PROCEEDINGS OF THE 32ND SOUTHERN PASTURE

AND FORAGE CROP IMPROVEMENT CONFERENCE

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THE FORAGE SITUATION

By William E. Barksdale [1]

The forage situation in the United States today can be described in several terms which are not entirely consistent with one another.

One could say that the forage situation in the Southeast and parts of the Eastern United States is currently very critical. A recent 3,500 mile, nine state tour of forage production and livestock enterprises revealed that beef cattle in general are in about as poor a condition as has been witnessed since the 1930's. This is because the heavy inventories of beef cattle now on farms as a result of low prices have overburdened forage supplies. This presents a challenge for future generations of forage farmers--we must not repeat this sort of experience. Obviously, the conditions will only worsen if we have dry weather this summer.

Another way to describe the current forage situation is to say that forages are gaining in value. Recent figures from the Statistical Reporting Service indicate that hay sold for an average of $31.30 a ton in 1972. In 1973 the average price was $41.71 per ton. The 1974 average price was $50.78 per ton. Similar increases have been noted in the per acre grazing fees being charged in various areas.

A third way to describe the current forage situation is to say that forages are receiving increased emphasis. A recent agricultural publication surveyed its readers, 90% of whom have some type of pasture and 74% of whom have some sort of hay crop. Seventeen percent of those who have pastures said they were increasing their pasture acreages in 1975 and 24% of those who grow hay said they were increasing their hay production this year.

On a more meaningful basis, however, I think it is accurate to say that the current forage situation is one of extreme optimism for the future--because, in my analysis, forages are on the threshold of a completely new level of value in American agriculture. I feel that this is a fact because of the new premiums which the world food economy has placed on the U. S. grain and oilseed supplies.

We Americans have been widely exposed to three myths about the increasing value of grain. We have been told that worldwide weather conditions in 1972 caused a temporary shortage of grain, but this is not a valid fact because 1972 was, at that time, the second highest grain production year in the world's history. We also have been told that the increased prices seen in 1972 and 1973 were due to a temporary leap in world grain consumption and that it would not be continued. This, however, is not a fact. World cereal grain production has increased by an average of 27 million metric tons per year since 1960.

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A third myth that we all have heard is that Russia bought all the grain in 1972 and 1973, and that this caused an unusually high grain price which will not be maintained. This is definitely erroneous. The amount of grain moving to the Soviet Union in 1972 and 1973 from the United States represented only 20% of the increased volume of grain moving from this country. The remaining 80% of increased volume of grain exports went to countries around the world.

Three factors which have caused demand for U. S. grain are a growth in world population, increasing affluence around the world, and, simultaneously, increased consumption of poultry and livestock.

All of these factors combined to place new world premiums on grains and oilseeds. This, in turn, places new priorities on the role of ruminant animals (primarily cattle and sheep) in converting forages to meat, milk and fiber.

In the past, the United States has utilized about 75% of its corn crop in feed for poultry and livestock. If, in fact, world customers are interested in utilizing a greater percentage of our U. S. grain now for human food, we can provide them increased tonnages of grain without sacrificing our standards of nutrition here in the U. S. We can simply utilize more forages and less grain in the production of meat and milk.

The United States is in a uniquely advantageous position to make such a transition in its animal agriculture. Of the 2.3 billion acreas of land in the Continental United States, about 1 billion acreas are currently involved in forage production. This land currently is producing at about 22% of its potential according to the American Forage and Grassland Council. At present levels the United States produces about 213 million Animal Unit Months from forages. This could be raised relatively easily through currently available technology to about 560 million Animal Unit Months--with an ultimate potential of about 1700 million Animals Unit Months possible.

An Animal Unit Month is the nutritional equivalent of about 8 bushels of corn. With corn at $3.00 a bushel, an Animal Unit Month from corn is worth about $24.00. However, an Animal Unit Month can be produced from forages for only $3.00 to $4.00. Obviously, American agriculture can produce a net profit of $20.00 to $21.00 per Animal Unit Month by exporting more corn and making better use of its forage resources.

According to Wedin, Hodgson and Jacobson, 73% of the feed units utilized by the American beef cattle population come from forages. Approximately 64% of the feed units utilized by dairy cattle come from forages, and about 89% of those utilized by sheep and goats come from forages.

Forages are big business. One way to consider the size of the industry is to appraise the value of forages as feed for beef and dairy cattle.

FORAGE VALUE RATING

	Feed As % Total Prd. Cost	% Feed From Forages				1974 Sales ($ Billion)		Value of Forage Contributions
Beef	75	75	=	.56	x	18	=	10
Dairy	50	65	=	.33	x	9	=	3
								$13 billion

Forages have some very special features. First, as you in this audience know so well, legumes in a grass pasture not only increase the nutritional content of the forage but also provide 100 to 200 pounds of nitrogen per acre

to fertilize the grass. This, obviously, attains new significance in these days of higher nitrogen fertilizer prices.

Conservation and erosion-preventing aspects of forages also have attained new significance in recent years as this country has become more aware of its environmental problems relating to agricultural practices.

Also, it is significant to remember that people in many undeveloped nations consider the ruminant animal their only promising link to better supplies of protein. These people have no money to import grain from the U. S. and other major grain exporting countries, and they do not have the soil, climate and other resources to utilize American row crop technology. They do, however, have the climate and abilities to grow abundant supplies of forages and they do know how to manage cattle. They simply need help in improving their efficiency in producing grass and cattle.

The South has a very unique advantage in forage production. It has a long growing season, adequate rainfall, a variety of species of forages, adequate acreages of non-row crop land, and relatively mild winters. I have seen, not too many miles from this very location, 30 cows and their calves being carried on a 30 acre pasture year around.

Additional emphasis will have to be placed on research if Americans are to make better use of their forage resources in the production of meat, milk and fiber. Approximately 498 scientific man years were devoted to research in forages, pasture and rangeland during 1973 in a total of 1279 projects. This compares to about 498 scientific man years devoted to research in cotton. However, one must consider that forages represent 15 or 20 or more different species, while cotton, of course, is only one. Obviously research needs to be intensified to aid American agriculture in its effort to better utilize forages.

Consumers will need to be educated about the value of making better use of forages. They will have to be informed that quality is not necessarily going to decline simply because an animal is brought to market weights utilizing more forages and less grain than has been true in the past.

Producers will carry an extremely big responsibility in making better use of forages. They will have to group their calving dates more closely to make best use of forages when they are available. For areas growing cool season grasses this will probably mean calving in the early spring. For areas where warm season grasses are grown with overseeded winter grazing, fall calving probably will be preferred. Cattlemen must breed their animals for maximum forage conversion abilities and they must plan to own their calves longer, selling yearling cattle instead of weanling calves. They will also have to make better use of fertilizer and such practices as rotation grazing and the utilization of crop residues. And, obviously, we all know that producers can do a much better job of harvesting forages for quality content in the future.

The American Forage and Grassland Council is striving to aid the entire agricultural complex in making better use of forage resources. AFGC is a clearinghouse of ideas and thoughts in reaching these objectives. Individual memberships cost only $10.00 a year--and the price has been held at that level to encourage you--the forage research and extension specialists, to participate in AFGC. The main burden of financial support comes from the corporate sector, where memberships sell for $150.00 to $500.00, depending on sales volume.

State Forage Councils have already been organized in about ten states, including at least three Southern states--Arkansas, Louisiana and Kentucky.

More councils are now being organized-- and I firmly believe that they should exist in states such as Texas, Mississippi, Alabama, Georgia, and others.

AFGC conducts an Annual Research-Industry Conference at which scientists, agribusinessmen and producers all have a chance to discuss their observations and findings in the forage field. AFGC also publishes Forage and Grassland Progress, a newsletter which goes to all members, as well as a special Corporate Members Newsletter.

The condition of the organization has improved vastly under its first year of having an executive vice president, Warren C. Thompson. AFGC has published a brochure which explains the role of the organization and the value of the forage resources of America and the organization also recently published a leaflet for aiding the organization of additional State Forage Councils. Annually, a membership directory is published, also.

AFGC has just initiated a program which will produce six new publication within the next year or less. These are as follows:

Managing Pastures to Maintain Legumes
Crops for Silage
Forage for the Dairy Herd
Forage for the Beef Herd
Fertilizing Pastures
Improved Pastures--Why and How?

AFGC has a special Hay Task Force which is investigating several areas of the hay industry including the bases on which hay is priced and the possibilities for more effective packaging systems for hay. About 20% of the total U. S. hay crop is sold in one form or another. In 1973 this amounted to 27 million tons of hay which sold for 1.2 billion dollars.

AFGC also will soon initiate a special panel of forage farmers which will be surveyed periodically to measure their results, attitudes, and intentions.

In conclusion, I think that forages face an entirely new future of utilization in the production of meat, milk and fiber for American consumers. Professional workers and producers who respond to the challenges ahead no doubt will face new opportunities in connection with this trend. We Americans simply must make better use of our resources for feeding humans--and a very critically important part of this total picture is the utilization of forages by ruminant animals.

FORAGES AND BEEF - STILL A WINNING COMBINATION

By L. S. Pope [1]

While there has been much furor lately over the wastefulness of heavy grain feeding of beef cattle. particularly in drylot fattening on the Plains, a fact largely overlooked is that it is primarily forage that produces the bulk of American beef. First, there is the maintenance of nearly 45 million beef cows, almost completely on range or pasture. Add to this the millions of acres of improved pastures for yearling cattle, plus eight million acres or so of wheat and small grains grazed during a normal winter, and millions of tons of silage and hay used both for growing cattle and in finishing rations.

So, when the critics of the beef industry talk superficially about cutting one hamburger from our diet and thereby increasing tremendously the grain available for human food, they should bring themselves up to date on the true nature of the inputs into a total beef production unit. For example, beef cattle utilize nearly 900 million acres of range and improved pastures in the U. S. each year - nearly 75% of our land total. This has no market outlet, in most cases, other than through the ruminant. And even with emphasis on drylot fattening of cattle, it is estimated that only 40% of the final weight of most finished steers is the result of the feedlot program. Therefore, about two-thirds of final weight is represented by the contribution of grass or harvested forage.

Rapid and dramatic changes in the U. S. beef industry over the past 18 months point to some permanent shifts in structure and organization - reaching down to every level of American beef production. So great has been the economic impact of developments during 1974 that the U. S. beef business may never be quite the same again.

What are some of these changes and what do they mean, particularly to cow-calf producers and feedlot operators? Let's take a close look at what is happening to agriculture's largest money-earner --- the production, processing and retailing of U. S. beef.

Unlike the '30's, the price collapse of 1973-74 hit a highly capitalized business, greatly dependent on other segments of agriculture and industry. We were caught with too many heavyweight, over finished cattle, together with bulging cow herds. Retailers held their margins high while live cattle prices collapsed. The fed beef market has remained "soft" for nearly 18 months. Continued financial loss by investors caused outside sources of capital to dry up. Since outside capital was one of the major factors bolstering feeder cattle demand, the result of withdrawal had a domino effect on feeder cattle prices.

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Coupled with this, the year 1974 marked a dramatic shift in the cost of feed grain. Many feedlots on the Plains were established on the concept of cheap grain. Grain alone makes up nearly 80% of the feed costs for fattening cattle. Thus, a sharp increase in grain prices was sufficient to drive costs right through the ceiling.

With a shorter-than-expected grain crop in 1974, many cattle feeders were reluctant to try it again. The results was the worst loss in feeder cattle returns since 1954. Obviously, grain supplies cannot be replenished before another crop is produced in 1975. Even then, some authorities believe we will have to see back-to-back record grain crops before the cost of grain comes down much since the export demand for corn and grain sorghum will remain strong.

What is likely to be the result of all this? Many experts in the beef business say we are witnessing the beginning of a vast change within our industry. They believe that the days of long-fed cattle, fattened on cheap grain for 180 days or more in drylot, are gone for this decade, perhaps forever. In the future, they believe, we will see more yearlings and cattle weighing 700 pounds or so, fed less than 120 days on heavy grain rations. The recent proposal to change the grading standards for beef carcasses with less emphasis on marbling, will certainly be a step in this direction.

Many predict that with world-wide grain shortages, we will see, at least locally, a return to "forage finished" beef. Experiments at several southern states, notably Louisiana, Georgia, and South Carolina, have shown that it is indeed feasible to fatten steers to an acceptable degree of finish on forage alone. Farmers in the Midwest have long understood the value of excellent corn silage, properly supplemented, as a ration for finishing steers to the Good-to-Choice grades.

However, before "forage finished" beef can be produced in volume, some sobering obstacles must be considered. For example, in most regions the production of excellent forage is a seasonal proposition. To be an important source of beef, it would have to be produced over a longer period than now seems likely. Further, most large packing operations have followed the feedlots west. Thus, local packers seem to be the best outlet for this type of beef and the supply will be seasonal.

What will be the consumer's reaction to a difference in beef quality, to the possibility of a slight yellow cast to the fat of grass-finished beef? Also, grass-finished cattle will yield less than those finished on heavy grain rations, thus killing costs per hundredweight of product will be higher. These obstacles must be considered before a serious inroad can be expected from "forage finished" beef as a part of our total beef system.

It seems logical that we will see a return to the fundamentals of beef production, to greater emphasis on weaning weights, greater use of winter and spring pastures in producing cheaper gains. Perhaps this is as it should be. Large commerical feedlots had an unlimited demand for nearly every feeder calf we could produce during the 1960's. By 1973, nearly 75% of our total calf crop passed through feedlots, large and small, before slaughter. In a real sense, feedlots dictated the direction of the entire beef industry.

Heavy weaning weights from fertile, highly productive crossbred cows will again resume their rightful importance. Cattlemen may look to combination cow-calf and yearling programs. Production of lightweight calves will be discouraged. These trends can be important for the beef industry. We should never have been diverted from this goal in the 1960's by the heavy demand for feeder cattle of any weight, shape or age.

Improved pastures for stocker calves and yearlings will also assume added

importance. The high cost of grain will encourage the feeder to buy weight in the form of heavier feeders, rather than feeding it on.

However, feedlots will still occupy a crucial position, if for no other reason than that they provide an assembly point for the finished cattle which must supply most of the 60 million pounds of beef consumed each day by hungry Americans.

But it will be a cattle feeding industry that will be only one part of the total beef system. No longer will large feedlots dominate the beef industry, rather they will provide the short, heavy grain-feeding phase which many believe is necessary to produce the "eating quality" of beef which Americans prefer.

Abundant forage, therefore, will become the key to profits in the next phase of the U. S. beef industry. Can we produce it economically, manage it efficiently and utilize it to greater advantage in the years ahead? That is the question that must be answered as we progress through the last half of the 1970's.

For one thing, it takes lots of forage just to maintain our cow herds and put gain on growing cattle. Estimates are that it takes about 125 million pounds daily just to keep our operations going in Texas. With this massive intake of forage, whether from native range or improved pastures, beef production has been relatively efficient as compared to other species. It has been calculated that due to the large percent of the total ration of the cow and growing calf derived from forage, it requires only 2.9 pounds of concentrates per pound of total gain on the finished steer at 1,100 pounds. This is only slightly above that required by the broiler, and even better than the pig.

However, events of the past two years have shown that forage is no longer a cheap feed, whether produced on native range (due to high costs of land) or on improved pastures (due to high cost of fertilizers). Costs per acre of establishing small grain pastures were estimated at $90/acre in East Texas last fall. Nitrogen shortages and high prices have stimulated interest in legumes - an almost forgotten subject two years ago! Likely, the costs of fertilizer will remain high and shortages will occur in phosphate fertilizers from time to time. Already, producers have begun to cut back on fertilizer use, as indicated by recent tonnage figures. After all, when calves were 60¢ per pound, it was easy to think of pasture fertilization. This year, many good pasture management and fertilization programs will suffer from the high cost of doing business.

While caught between the "rock and a hard place", the producer should consider the costs of not fully utilizing all his resources to the maximum in modern beef production. When forages are not fertilized so as to yield maximum tonnage, other costs of production increase, percentagewise. Interest on investment, taxes, labor, and operating costs still continue whether or not cows wean a larger and heavier calf crop or yearling cattle gain 1.0 versus 1.5 pounds per day. When all costs are considered, cattlemen are "locked in" to a rather rigid set of economics and maximum production of forage remains the key to profits.

Lastly, let's not be too pessimistic about the future of beef. In 1975, lucky Americans will consume the greatest tonnage of beef ever produced in U. S. history. And they will pay little more in terms of percent of disposable income for beef in 1975. Few other items in our inflated economy fall in this class. But Southern beef producers in 1975 and beyond will need a better "systems approach" to beef production. Starting with "custom built" cattle, genetically engineered to be highly fertile, grow rapidly and produce a superior

carcass, the beef man will use every management tool and technique to increase output per cow unit. Forage, obviously, will be the key to success.

There's an old adage in the beef business: "Fit the cattle to the feed supply." This implies "fine tuning" of cattle and feed resources to obtain maximum yield at minimum cost. It will require investments in cattle and feed to do this. Shorting beef cattle on an ample supply of forage may be the most costly mistake in the beef business today, since costs of other items of production continue to mount as cattle stand still in performance.

Nearly all experts agree that the long-range outlook for beef is good, despite current economic problems. We can do the job of producing lean, thrifty beef for U. S. consumers and still return a decent profit only by the "forage route" since the long-range picture calls for rather high grain prices through the remainder of the 1970's. Southern cattlemen need your help to assure a continued output of millions of pounds of carcass beef daily - and you need a profitable cattle industry to make your efforts worthwhile. Together we form a winning combination. Let's hope the lucky U. S. consumer appreciates our efforts.

THE FERILIZER SITUATION: PRESENT AND PROJECTED

By Edwin A. Harre and Gerald G. Williams [1/]

The U. S. fertilizer industry has made a full cycle. In the last two years it has unmired itself from five years of overcapacity, overproduction, minimal growth in demand, excessive inventory levels, and low profits where any existed at all. During this time, new plant construction was almost at a standstill because of the poor economic condition of the industry. When the demand for fertilizer materials did pick up again in 1974, the lack of sufficient capacity led to shortages in the supply of all three primary plant nutrients and prices increased rapidly. However, now the exaggerated profit picture of the last few months is stimulating new investment in the industry, and supply is once again increasing faster than demand.

Fertilizer Prices

The recent rise in retail fertilizer prices is shown in Figure 1. The price freeze imposed in 1970 came at the lowest level that fertilizer prices had reached in many years. With little prospect for adequate returns on investment, plant construction stopped, and producers searched for new markets. In October 1973 in an attempt to increase domestic supply levels that had become abnormally low because of the attractive export market, price controls were removed. Fertilizer prices doubled almost overnight. They have continued moving upward since then--out of proportion with agricultural commodity prices which began to stabilize or decline during 1974. With relatively unfavorable ratios of farm output to fertilizer price, the farmer has taken a second look at his soil fertility needs. Instead of demanding more plant food he is calculating the lowest level he can use without suffering a significant yield reduction. Today the bubble has burst, fertilizer materials are stacked in warehouses all over the country, and fertilizer prices are backing off from recent high levels.

Fertilizer Inventories

The wet spring weather and the fact that many farmers had purchased and stored fertilizers prior to the spiraling price change of the last few months left producers--who had pulled out all of the stops to increase production--shipping to storage rather than to the retailer or farmer. Inventory levels that had been virtually depleted in 1973, as indicated in figure 2, were on the climb once again, and it should be remembered that this measurement of stocks

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on hand is taken at the producer level which only begins to accumulate after retail and regional storage areas have been filled. As we end the 1975 fertilizer season, it is apparent that demand did not reach expectations and that the normal spring drawdown in inventory will not deplete stock levels to their normal lows.

The supply position for each plant nutrient is not the same. Each has experienced different market prospects and restrictions. A brief discussion of the future supply-demand situation through 1980 for the U. S. nitrogen and phosphate industries and the North American potash producers follows.

Nitrogen

Nitrogen use has increased more rapidly than either phosphate or potash, averaging better than a 7.8 percent annual increase during the last decade. Farmers are now applying twice as much N in relation to P_2O_5 or K_2O. By 1980 TVA has forecasted a continuation in this growth pattern; however, at the reduced annual rate of near six percent. If this rate of gain is achieved, it is expected that the U. S. farmer will be applying 12.5 million short tons of nitrogen to his soils.

It has recently been thought that the U. S. would be unable to supply the U. S. farmer with this amount of material from domestic production. A return to our net import position was expected to last indefinitely as critical shortages of natural gas have put a damper on any expansion plans for the industry. But the attractiveness of the market and the risks involved in the investment in plants and equipment in foreign countries has brought about a number of new ammonia plant announcements for construction within the boundaries of the U. S. As indicated in Figure 3, the majority of these new plants is scheduled to begin operation in 1976 and 1977. At this time, the industry will once again be in a position to produce enough nitrogen to satisfy the domestic market and have an exportable surplus.

Total nitrogen production capacity in the U.S. is just over 15 million tons N and is projected to reach over 21 million tons N by 1978. At a 90 percent operating rate and considering processing losses and the nonfertilizer market demands, this level of capacity will result in a potential nitrogen supply for fertilizer of over 13.5 million tons N by 1980. While comfortably above the projected demand of 12.5 million tons for the same year, it does not account for any possible closing of plants during the interim when a surplus exceeding 13 percent of the projected demand is expected. Considering the age of many smaller ammonia plants in the nation plus the marginal economic position of some of the smaller scale units recently reconditioned and brought back into production, it is reasonable to assume that more than a million tons of ammonia capacity will be phased out in the next few years. If this is the case, by 1980 the nitrogen industry could be facing the need for additional capacity as the supply cycle continues to move through periods of deficits or surplus.

One factor in the nitrogen market that cannot be overlooked is the recent announced expansion of ammonia plants in the Canadian province of Alberta. Natural gas reserves are abundant in that region and offer an alternative supply source for the U. S. market. Two plants of 400,000 tons each of ammonia are under construction with six others of similar size approved by the Alberta Energy Board. These units still await approval by the Provincial government. If they come into production as currently scheduled, however, North America will have ample nitrogen supplies and will need to establish itself as a major

world nitrogen supplier in order to achieve a domestic supply-demand balance within reasonable economical operating rates for these new plants.

Phosphates

It is difficult to project future growth in the use of phosphate fertilizers. Over the last 30 years this market has increased at an annual rate close to 4.5 percent. In recent years growth has slowed, but the market has continued to expand. However, present farmer uncertainty, poor weather conditions, and adequate P_2O_5 levels in many soils suggest that use in 1975 will be significantly below previous levels. The question of the future use of phosphate materials under more favorable price relationships with agricultural commodities in view of soil reserves remains to be answered.

The argument may be academic. Regardless of the optimism or pessimism applied to the demand forecast, it is apparent that future supply levels will be more than adequate to satisfy demand and keep exports well above current levels. As indicated in Figure 4, the large scale expansion program initiated in 1972 because of anticipated favorable export market conditions is now coming into production. Four new phosphoric acid units began operation this spring, raising the nation's phosphoric acid capacity by almost two million tons of P_2O_5. Additional units tentatively scheduled for the remainder of the decade would bring total capacity to near 10 million tons by 1980, thus the wide divergence between supply and the most optimistic of demand estimates as presented in figure 4.

Phosphate rock producers have undergone the same market problems faced by the nitrogen and phosphate industry since the middle of the 1960's. Little expansion has taken place in production, sales have exceeded production since 1968, and a steady inventory reduction has taken place. Recent price changes also brought about large scale expansion in rock mining in the U.S. and there now is not expected to be any limitations on phosphate fertilizer production from a short supply of phosphate rock.

Potash

During the 1974 fertilizer season, potash producers enjoyed one of their best years. Reported deliveries were up 20 percent over the previous years and consumption increased faster than either nitrogen or phosphates. Canadian producers were allowed to operate without quotas for the first time since 1970; however, significant production increases were not immediately forthcoming since additional investment was needed to bring long idle facilities up to full production levels.

As seen in Figure 5, North American potash producers will need to operate their plants at more than 70 percent of the total capacity presently available. A 10 percent increase in the overall production level should assure adequate supply levels for the North American domestic market and allow a continuing expansion of offshore trade of up to about two million tons by 1980.

Canada now supplies about 75 percent of the U. S. potash market with production from Carlsbad, New Mexico, making up the remainder. Recently there have been some announced expansions at the potash mines in New Mexico. However, with the exception of the reopening of one plant, little in the way of additional production is expected. In the future the supply of potash for the U. S. market should remain adequate as long as there are no restrictions imposed on producers that would discourage any necessary investments in plant and equipment.

Summary

Once again, the laws of supply and demand have brought the fertilizer market through another cycle. After the short supply levels of the 1973 and 1974 fertilizer years, increased price levels have stimulated investment in the industry and new capacity is becoming available to satisfy the market demands. Phosphate and potash supplies should be ample for the remainder of the decade, while nitrogen supply will follow by 1977. The future supply-demand balances and the prosperity of both the farmer and the fertilizer industry will depend on maintaining an equitable price relationship between agricultural commodities and fertilizers. Fertilizer remains a vital input in the nation's agriculture, and its use will continue to expand as long as the farmer continues to receive a favorable benefit-cost ratio with its use. Generally speaking, the problems of the fertilizer industry in the last decade stem not from lack of demand but from overreaction on the supply side of the equation.

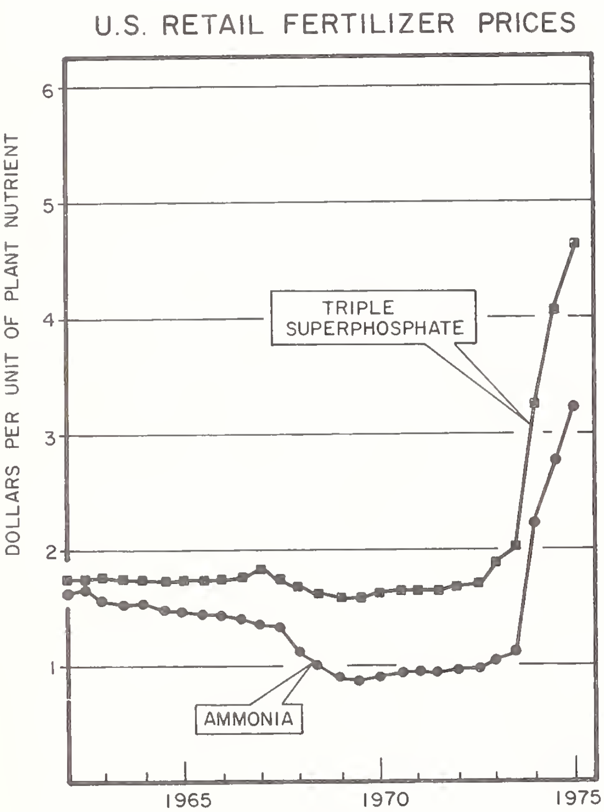

Figure 1

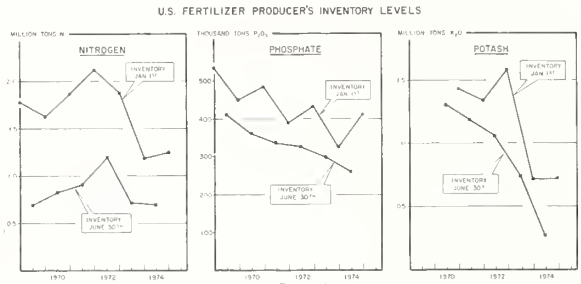

Figure 2

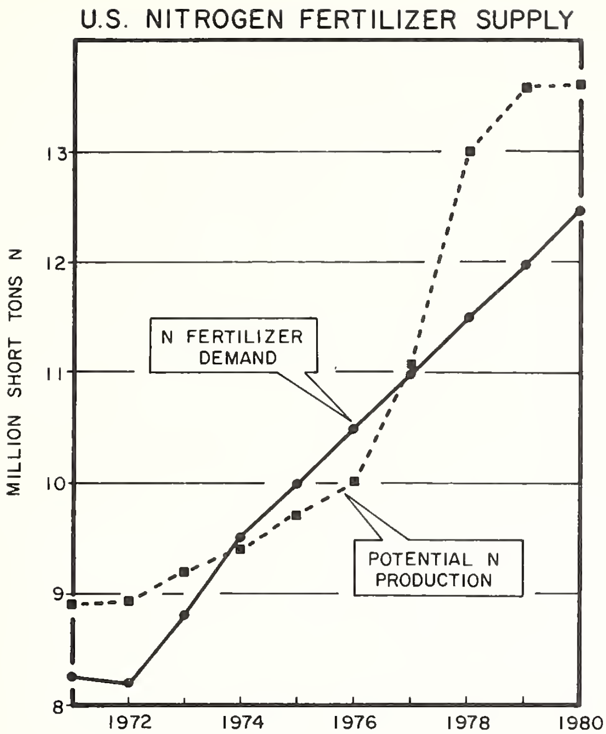

Figure 3

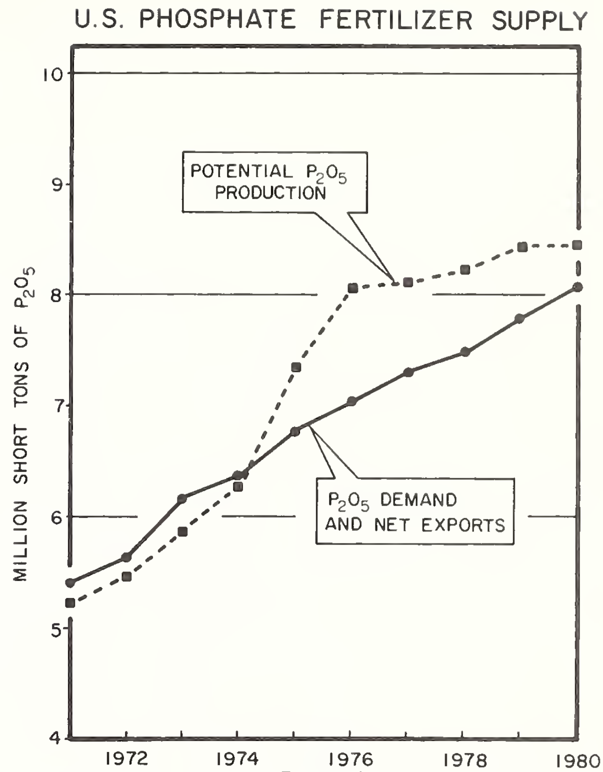

Figure 4

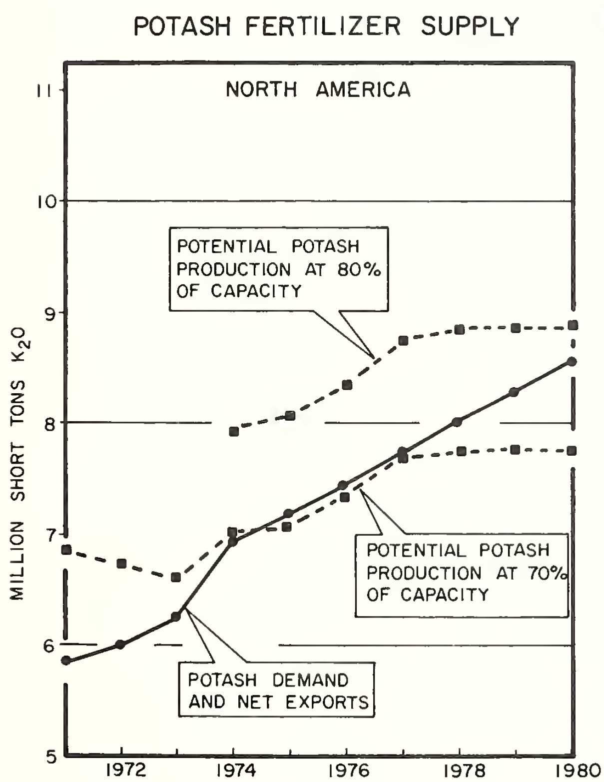

Figure 5

FOUNDATION SEED PROJECT

By C. S. Garrison and C. M. Rincker, ARS

BACKGROUND

The Foundation Seed Project was approved in 1948 and has operated continuously to date. The purpose of the Project is to "build up quickly and to maintain foundation seed of superior grass and legume varieties". Operational phases are concerned only with producing, assembling, distributing and limited stockpiling of foundation seed. Technical, operational and financial support for the project is provided jointly by the Agricultural Research Service and the Commodity Credit Corporation. A Memorandum of Understanding between ARS and the Agricultural Stabilization and Conservation Service, representing CCC, was signed in May 1949. The most recent revision of the M/U was approved on October 5, 1970.

The Project continues to play an important role in the rapid multiplication of many improved forage varieties used extensively in the humid regions of the country. Without this program some varieties would not be making the contribution to livestock feed production as is currently the case; others would have been available to farmers only in limited supply.

In the mid 1940's, superior forage varieties were grown on less than two percent of the acreage. A study by Administrators in the U. S. Department of Agriculture and the State agricultural experiment stations showed the major factors responsible for this situation were: 1) The failure to develop seed production programs for many small seeded grass and legume varieties in favorable environments in the western States; this is in contrast to the local production of cereals and oilseed crops. 2) No organized program for the production and maintenance of inventories of foundation seed of the superior forage varieties. 3) Inadequate educational programs.

These three factors have the same importance today as they did 30 years ago although some States have expanded their foundation forage seed activities. Each has a significant bearing on the success of varietal releases from public breeding projects. Inadequate educational programs emphasizing improved varieties is still a major limitation.

The Foundation Seed Program has built up and maintained foundation seed of forage crop varieties used extensively in the Central, Eastern and Southern States. To facilitate the maximum increase of new grass and legume varieties, the Foundation Seed Program is authorized to assist breeders in maintaining breeder seed and, as may be necessary, to accumulate small supplies of registered seed. During the 25 years of operating this program, CCC has not sustained any long-term financial losses. In fact, there has been a small net gain of $300,000 to $400,000 during the period. ARS participation is covered by funds appropriated annually.

The operational phases of the program, namely, production, processing,

storage, and distribution of foundation seed is cooperative with State agricultural experiment stations, State seed certifying agencies, State foundation seed organizations, and seed firms. Each cooperating agricultural experiment station assigns a State foundation seed representative to assist with Project operations in that State.

The production and distribution of adequate and recurring supplies of foundation seed is the final stage in the breeding and release of superior varieties. This type of support program is required if the investment in forage breeding is to pay dividends by increasing feed production efficiency. Frequently, new varieties are not multiplied in the quantity needed to meet demand because of inadequate foundation seed. Such varieties as Cumberland and Midland red clover; Atlantic and Buffalo alfalfa; Tift sudangrass; and Climax lespedza failed to meet their full potential because of "too little and too late" effort into the production of foundation seed.

On the other hand, Vernal alfalfa was taken into the Foundation Seed Project at the time of its release in 1953. Eighteen months later there was over 1.8 million pounds of certified seed. In comparison, only 1.1 million pounds of certified Ranger and 14,568 pounds of certified Atlantic alfalfa seed were produced six and eight years following release. The maintenance of foundation seed supplies has made Vernal the most widely used alfalfa variety in the U.S. today. To date more than 280 million pounds of certified Vernal have been produced. This quantity is second only to the record for Ranger which is nearly one billion pounds.

Certified seed of Cumberland red clover never was available in adequate supply because stock seed was continually siphoned off and used for forage plantings in the Eastern States. Had there been a program to maintain recurring supplies of foundation seed, this variety would have been used extensively for hay and pasture. Midland red clover adapted to the North Central States fell by the wayside for the same reason. A committee of the International Crop Improvement Association (AOSCA) tried to coordinate supplies of foundation seed. However, because of limited financial resources, it could not build up and maintain reserves of foundation seed.

Another example of the importance of an adequately financed foundation seed program is the record with Gahi 1 pearl millet. This variety was developed at the Georgia Coastal Plains Experiment Station and released for use in the Southeastern States. Foundation seed supplies have been maintained by the Project. In 1963, there was extensive propaganda by the seed trade to encourage farmers to plant sudan-sorghum hybrid seed on the Coastal Plain soils in the southeast. This caused a sharp reduction in demand for foundation Gahi 1; zero in 1965. However, the Foundation Seed Project retained its inventories. This resulted in foundation seed being readily available three years later when the demand for planting stock seed was regenerated following poor performance of the sudan-sorghum hybrids on the light soils. In the late 1960's certified Gahi 1 seed prices dropped severely so that it was not profitable for many growers to produce seed; therefore, there was a reduction in the demand for foundation seed. However, the Project carried over reserves and in 1973 was able to meet the largest demand for foundation Gahi 1 seed. Thus, the Project maintains foundation seed supplies for current distribution and carry-over inventories to assure the availability of planting stocks over the long-term. Otherwise, varieties such as Gahi 1 would "die" and be lost to agriculture.

Many of the seed firms with their own breeding programs are interested primarily in the production, distribution, and promotion of their own proprietary varieties. They have not shown the same interest in handling seed of

publicly bred varieties unless they were granted exclusive rights to these varieties. For example, the initial foundation seed of Apalachee alfalfa from the North Carolina Agricultural Experiment Station was released to two seed firms for multiplication and distribution in the area of usage. Four years later there was no reported production of certified seed from these releases. The new Arc alfalfa was released in 1974, 50 percent of the 417 pounds of reclassified breeder seed was distributed through State foundation seed programs, the remainder through two seed firms. The former was planted and most of the acreage produced a seed crop in the seeding year. The foundation seed distributed to the seed firms was not planted until late last fall. According to reports, the firms were too involved with proprietary varieties to arrange for the multiplication of the ARC stock. Approximately 22,000 pounds of certified Arc seed will be distributed in the mid-Atlantic States in 1975 for forage production.

Varieties developed by the Agricultural Research Service in cooperation with the State agricultural experiment stations are not likely to be released on an exclusive basis in the near future because of recent court ruling. Since the large seed firms have proprietary varieties which give them exclusive marketing rights, they are not interested in maintaining the foundation seed reserves of non-exclusive public varieties which must be distributed equitable to all qualified growers who request seed. However, a large number of smaller firms use the public-released varieties as the backbone of their seed business.

Current Operations

The Foundation Seed Project like other activities has suffered from increased prices, costs and inflation. The salvation to date has been the seed in inventory produced prior to 1973 when prices paid growers were 40% to 90% lower than those in 1973 and 1974. Because of the high sale prices and the FIFO method of managing inventories CCC has made limited unplanned monetary gains. These gains may be needed should there be a major break in grass and legume prices in the future. Recent sale prices established for Foundation seed were higher than the purchase price would justify. However, it was necessary to raise the sale price for foundation seed to protect inventories. For example, a seed firm inquired about the purchase of 50,000 pounds of foundation Vernal at the established foundation seed price of 90¢ per pound. At the time, certified seed growers were being paid $1.20 to $1.35 per pound for their certified seed. Thus, the project was forced to escalate the sale prices to avoid depletion of its inventories--the seed to be used for forage planting.

Foundation seed production, distribution and inventory. In Table 1, we have summarized data on the distribution of foundation seed by variety in 1973 and 1974; the estimated production in 1974 and the current carry-over inventory on January 1, 1975. The latter does not include the 1974 production. We need to build up the supply of Ramsey alfalfa. And of course, do better with Agate with which we had one of our occasional failures this past year; the field did not meet certification requirements. The details are given as footnote 4 in Table 1. The supplies of the other varieties are adequate particularly in view of the reduced grower interest in producing certified forage seed. Wheat, sugar beet, potatoes, some vegetable seed crops, etc., are too competitive and can be grown with less risk.

Tables 2 and 3 include the annual production and distribution of foundation Vernal and Gahi 1 seed. Dr. Brink requested the Vernal information and we used the Gahi 1 data for another purpose. We have similar tables for the other

varieties if they are of interest. At the time we prepared the report for Dr. Brink, we were surprised by the quantity of foundation Vernal that has been produced and distributed since its release in 1954. The production of foundation seed has amounted to 1,826,398 pounds; distribution 1,592,290 pounds and the total production of certified seed at approximately 280,000,000 pounds according to AOSCA reports. The current CCC inventory of foundation seed as of January 31, 1975 amounts to 234,108 pounds. It is stored in three warehouses (Caldwell, Idaho; Madras, Oregon; Wapato, Washington) to protect against losses from fire and other calamitous events.

TABLE 1.--Foundation Seed Production, Distribution and Inventories Foundation Seed Project - January 1975

	Distribution		Production	Carry-over Inventory
	1973 lbs.	1974 lbs.	1974 lbs.	Jan. 1, 1975 1/ lbs.
Alfalfa				
Agate	1,677	4,218	2/	--
Apalachee	--	--	1,394	--
Arc	--	427	14,500 3/	--
Ranger	4,890	6,428	1,200 3/	--
Ramsey	--	--	1,900 3/	--
Team	930	9,240	--	4,950
Vernal	84,030	25,680	93,009	141,099
Birdsfoot trefoil				
Empire				
Red clover				
Arlington	--	--	38,000 3/	--
Kenland	15,742	4,098	20,000 3/	10,830
Kenstar	--	--	37,000 3/	--
Lakeland	14,100	10,740	31,000 3/	93,623
Pennscott	17,640	9,270	--	14,190
White clover				
Tillman 5/	--	--	--	465 1,068 (Registered seed)
Crownvetch				
Chemung	55	750	--	900
Orchardgrass				
Potomac	5,910	990	11,617	15,449
Timothy				
Verdant	1,020	2,010	--	3,570
Pearl millet				
Gahi 1	37,767	14,259 6/	--	0 (Blend of
Line 13			15,692	0 lines 13-18-23-26)

TABLE 1.--Continued

	Distribution 1973 lbs.	Distribution 1974 lbs.	Production 1974 lbs.	Carry-over Inventory Jan. 1, 1975 1/ lbs.
Line 18			2,076	19,190
Line 23			9,646	672
Line 26			6,376	12,750
Starr	4,500	1,619	15,286	--

1/ Inventory does not include the 1974 estimated production of foundation seed.

2/ A twenty six acre Agate field was established with breeder seed for the production of foundation seed. It failed to meet isolation requirements for certification. After the field was planted a neighbor farmer seeded an alfalfa hay field too close.

3/ Estimate of seed crops in process of being cleaned and certified. Will be added to inventory as soon as available for purchase by CCC. Foundation Vernal was purchased in mid-January.

4/ Foundation is distributed by the New York Seed Improvement Co-operative, Inc., Ithaca, New York.

5/ Tillman white clover is a "difficult" variety to handle. It's average yield has been lower than Ladino and other similar varieties. White clover seed production, at best, is not popular with growers except in a few isolated areas. With Tillman's low yields and economic competition from other crops, this variety doesn't have a bright future. We were successful in 1974 in building up the breeder seed supply of the three single crosses from vegetatively propagated material representing the six parental clones.

6/ Distribution of foundation Gahi limited in 1974 due to shortage of line 13 seed. A small crop was harvested in 1973 as a result of an irrigation pump failure. The unexpected large demand for foundation seed in '73 reduced our carry-over inventory of line 13 below the safe limits--a minimum of one years seed stock requirement. We harvested a poor crop of line 18 in '74 again because of a pump failure. However, there is and estimated two-year supply on hand.

TABLE 2.--Vernal Alfalfa Seed Production

Year	Seed Production Foundation lbs.	Seed Production Certified lbs.	Seed Distribution Foundation lbs.	% of Alfalfa Forage Acreage Planted to Vernal[2] U.S.	% of Alfalfa Forage Acreage Planted to Vernal[2] NC Region	Vernal Acreage in Wisconsin[2] 1,000 Acres
1953	9,599					
1954	13,875	1,813,247	9,599	3/		
1955	16,602	4,828,559	13,875	3/		
1956	70,979	6,351,089	16,602	3/		
1957	132,526 1/	7,945,892	70,979	4.2	4.8	--
1958	153,479	9,986,472	91,347	7.9	10.5	--
1959	291,905	10,870,256	105,467	12.0	14.6	--
1960	102,390	12,291,990	147,780	12.0	14.0	1,356.5
1961	--	12,643,225	101,246	17.1	19.9	1,800.0
1962	80,010	13,650,283	176,249	18.4	23.4	1,950.0
1963	63,060	11,417,863	134,349	19.5	23.5	2,000.0
1964	156,910	16,007,540	68,130	22.4	27.3	2,664.0
1965	203,932	12,117,940	128,332	23.6	27.7	2,678.0
1966	141,623	19,520,997	35,528	24.3	29.1	2,670.2
1967	--	18,423,936	44,116	24.0	30.3	2,670.0
1968	--	13,193,909	67,950	3/		
1969	--	18,691,481	95,558	23.6	29.8	2,217.0
1970	221,932	21,233,543	82,400	3/		
1971	84,567	20,340,070	58,423	3/		
1972	--	16,699,440*	34,650	3/		
1973	--	16,555,110*	84,030			
1974	93,009	15,966,060*	25,680			
Total	1,826,398	280,548,902	1,592,290			

* Estimate on the basis of the weighted average yield per acre of 510 lbs. for 1969, 1970 and 1971 multipled by acres approved for Certification as reported by AOSCA.

1/ The first year supply exceeded demand. Since 1957 the Foundation Seed project has maintained a reserve inventory of foundation Vernal seed. Thus foundation seed has been available to fill all requests except for the period July 20, 1964 to December 16, 1964 when our reserve was sold out. Our current reserve inventory is 222,221 lbs. (June 15, 1973).

2/ Trends in Forage Crop Varieties, Federal Extension Service, USDA Publications.

3/ Reports not published.

TABLE 3.--Production and Distribution of Foundation Gahi 1

Year	Production Lbs.	Distribution Lbs.	Shrinkage Lbs.	Inventory Lbs.
1958	27,479	--	--	27,479
1959	111,290	11,040	--	127,729
1960	6,600	17,884	--	97,974*
1961	0	20,858	1,095	76,021
1962	8,462	28,100	1,706	54,677
1963	98,003	30,664	1,651	120,365
1964	21,840	13,954	1,595	126,656
1965	0	0		
1966	0	16,250	--	110,406
1967	9,027	30,131	930	88,372
1968	0	35,658	514	52,200
1969	69,970	26,700	650	94,820
1970	0	9,150	--	85,670
1971	0	18,300	--	67,370
1972	20,350	19,342	258	68,120
1973	40,501	37,767	128	70,726
1974	33,790	14,259	--	44,540**

* 18,471 lbs. taken out of inventory because of genetic impurity.
** 11,927 lbs. removed from inventory due to poor viability.

The distribution of foundation Gahi 1 seed now amount to approximately one-third of a million pounds; production over 440,000 pounds. In 1974, even though there was an inventory of 70,726 pounds of the inbred lines, we were able to make available only 14,259 pounds of foundation seed because of a shortage of line 13. An irrigation well failure reduced the production to a very small quantity thus this limited the amount of foundation Gahi 1 seed that could be composited for distribution in the spring of 1974. As the production record in Table 1 indicates, we have a good supply on hand of all four lines and will be able to meet total demand. Experience has shown inventories should be maintained at a 2-year supply; never should reserves be permitted to drop below a 1-year planting requirement. When the inventories get below the safe operating level then, by chance of course, we seem to encounter low yields or crop failures. At least when you have adequate reserves the foundation seed crop failures cause minimal concern.

Foundation seed production contract. We have requested CCC to review the section in the production contract detailing the price that will be paid for foundation seed. To date, it has provided for a fixed price schedule based on the average yield for the area at a standard price and any seed above this quantity at an excess seed price. This revision is necessary to provide more flexibility in pricing seed in relation to the fluctuating certified seed markets and returns from competitive crops. Because the contract was not amended in time for use in 1974, all the foundation seed except pearl millet was produced under a verbal agreement with the growers. The understanding was that CCC would purchase their foundation seed after the crop was harvested based on the average certified seed price for the crop in the area plus a reasonable premium for foundation seed. The production contract used in 1975 will incorporate a flexible pricing structure. For example, Vernal is by far the variety produced in the largest volume. It is logical, therefore, to tie the contract

price to the certified Vernal seed price on a given date plus a premium for foundation seed. One recent problem has been that certified Vernal to the grower is 10¢ to 25¢ per pound below the contract for proprietary varieties. This situation may well have resulted from the exceedingly high certified alfalfa seed prices paid growers during the 1973-74 marketing season. This influenced pricing in the 1974 contracts.

We believe 35¢ per pound is an adequate premium above certified seed for foundation seed. Our 1974 alfalfa prices were a little over this figure--about 45¢; Arlington and Lakeland red clover a little under it--about 25¢ to 30¢ and Kenland and Kenstar just about on the mark.

We had a verbal agreement with the growers that we would purchase their 1974 seed based on prices of certified seed in early December. We prefer the contract! I'm not a good negotiator--to sympathetic to the "tails of woe" from the growers. They almost had me crying too. There was some justification; alfalfa yields at 250 to 350 pounds per acre and red clover at 350 pounds. On a few farms the same land would have produced wheat yields of 80 to 100 bushels to the acre; at $5 per bushel.

Prices for 1974 foundation seed crop. CCC is paying $1.40 per pound for foundation alfalfa seed produced in 1974; except Apalachee which is $1.85; $1.35 for foundation Lakeland and Arlington red clover and $1.50 per pound for Kenland and Kenstar; 50¢ for Gahi 1 pearl millet and 45¢ for Starr and 75¢ for Potomac orchardgrass. The difference in prices for the red clovers relates to yield potential of Lakeland and Kenland over years in the Columbia Basin. However, it isn't possible to adjust for the seed grower factor. Two seed growers have produced most of the Lakeland--probably the two best growers who have produced red clover seed for the Project. They have high average yields--the best was 1600 pounds per acre on 28 acres.

If you have suggestions for the best procedure for pricing foundation seed in the production contract, please give us your ideas. We would welcome them.

Foundation seed production in 1975. In the coming year we will replenish our supplies of Agate, Ramsey and Arc. We believe the inventories of the other varieties are adequate for the time being. For Vernal, we estimate the inventory on hand will meet the demands for the next three to five years depending on the economics of alfalfa seed production versus other cash crops. Our primary problem at the moment is locating a good foundation Agate seed grower. The Ramsey grower should produce a thousand pounds per acre in 1975. There is large acreage of Arc eligible to produce foundation seed.

Although the demand for foundation red clover seed is down from previous years, we will start a new filed of pennscott in August to meet any unanticipated future demand. After we get a fix on demand for foundation seed of other red clover varities this spring we will consult with the orginators, consuming states and the seed trade to decide whether additional acreages should be established in late summer 1975. Barring any unforeseen circumstances the production of each of the red clover varieties should be similar in 1975 to that listed for 1974. Each field will be producing the second seed crop except a new 25-acre seeding of Kenland.

A new field of Potomac orchardgrass is under production in Western Oregon. In addition to our inventory the Foundation Seed Project, Oregon State University is also holding approximately 10,000 pounds of foundation Potomac anticipating farmer shift from wheat back to grass seed production.

We have arranged to grow 15-20 acreas each of the four Gahi 1 line in 1975. The inventory of Starr will be adequate for two years since the registered class is included for this variety. The foundation seed representative in Minnesota will arrange for the production of an additional field of Verdant timothy.

Future contract production. For the Foundation Seed Project to provide recurring supplied of foundation seed, it is necessary to make contracts with seed growers for several years production. This is an essential component of the successful program. To do otherwise would not provide a basis for the recurring seed supplies, and in addition would require the plant breeder to devote more of this time to breeder seed production and less to breeding new varieties. Commitments have been made to growers for the production of foundation seed and have informed them of the quality standards that must be met. We feel an obligation to these growers as well as the State Agricultural Experiment Station whose varieties are included in the program and a responsibility to produce and distribute foundation seed in an equitable manner to meet the total demand from the seed industry.

Bagging requirements. The bagging requirements were changed based on the recommendations of the Planning Conference last spring. The vote was slightly in favor of the change to single 50 pound units. It was interesting that states purchasing foundation seed generally preferred the 30 pound units. There was almost unanimous agreement that paper bags should not be used even though the bagging costs per pound of seed would be 40 to 50 percent of the cotton bags. About a year ago the cost of double 2.35 osnaburg cotton for 30 pound units was estimated at 4¢ to 5¢ per pound, whereas the single 50 pound units would be about 1 1/2¢. There will be some operational problems in shifting bag size since, for 25 years, the 30 pound unit has been standard except for pearl millet which was 50 pounds. For sometime into the future, we will have both 30 and 50 pound units available of several varieties such as Vernal or Lakeland.

Commodity Credit Corporation. In September 1973 the CCC Board of Directors indicated their desire to discontinue acting as banker for the Foundation Seed Program. This was in line with their general objective to minimize price support stock piling activities. The funds for the Foundation Seed Purchase Program are not in the category of price support. However, it was the general feeling of the Board at the time that withdrawal from the foundation seed activities would be in order. The proposed recommendation of the Board expressed the opinion that foundation seed production responsibilities for public varieties should be turned over to the seed firms. You will recall that Dr. Graumann asked for your evaluation in February 1974. Also AOSCA and the ASTA were asked to review the proposal. Numerous letters were sent to ARS, CCC, the Secretary of Agriculture and Congress requesting continuation of the Foundation Seed Project.

After a thorough review of these communications, a report from the Agricultural Research Service, ASCS discussions with members of the seed industry and consultation with other people, Commondity Credit Corporation has advised ARS it will continue its participation in the Foundation Seed Program and have suggested another review the latter part of 1975.

Appreciation. In completing this report we want to give special credit to the plant breeders who make available the breeder seed, the State foundation seed representatives appointed by the Directors of the cooperating state experiment stations, the state certifying seed agencies and seedsmen who make this Project. We offer our thanks--for without these significant inputs the Department's managment costs would multiply several fold; there would be a reduced operating efficiency and it would not be possible to facilitate the production of certified seed of improved forage varieties in this manner.

FORAGE FED BEEF CHALLENGES IT PRESENTS

By Joseph C. Purcell [1/]

Historical Perspective

Forage fed beef is not a new concept or a new practice. Prior to World War II, most of the beef produced in the United States moved directly from grass to slaughter. In some areas, these cattle were more than three years old and weighed up to 1,500 pounds -- these were commonly designated as "export" cattle. This term was a carryover from the era in which live cattle were shipped to England.

However, beef production systems changed -- gradually during the 1950's and more rapidly during the 1960's and through 1972 when most of the U. S. beef slaughter excluding cull cows took a turn in the feedlot prior to slaughter (Statistical Reporting Service, U.S. Dept. of Agr. Cattle on Feed (Selected Issues) and ____ 1973. Livestock and Meat Statistics. Stat. Bull. No. 522 and Supplements). The grow-out and finishing period was reduced from three years or more to approximately one year to 18 months depending on the grow-out system.

U.S. consumers took to young grain-fed beef like ducks take to water. Between 1950 and 1973, the demand for beef increased 54% per capita. Real (deflated) cattle prices were nearly the same in 1950 and 1973 with the per capita consumption at 72 lbs. in 1950 and 111 lbs. in 1973 (Ibid. Cattle prices deflated by the U.S. Dept. of Commerce. Survey of Current Business (Selected Issues)). With only two minor exceptions, both the per capita quantity of beef and the real price received by producers increased consistently from 1964 through 1972. Also, the price of cattle increased relative to the price of feed grain during this period (Statistical Reporting Service. U.S. Dept. of Agr. Agricultural Prices (Selected Issues)). This was truly the golden era (1964-72) for the U.S. beef business with everyone reasonable happy including the consumer.

Then came 1973 and 1974 when the bubble rose and collapsed for the U.S. beef industry. First we had a consumer rebellion against excessively high beef prices followed by government intervention in the market in the form of price ceilings in early 1973. This led to excessive withholding of all types and sizes of cattle during the first three quarters of 1973. The excessive backlog of cattle broke the market in late 1973. At the same time grain prices were rising and was further augmented by the extremely small grain harvest in 1974. Cattle feeders suffered heavy losses and responded by drastically reducing the price paid for feeders. Topping it off, the economic recession in 1974-75 has resulted in a sharp decline in consumer demand for beef.

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The History Lesson

Was 1974 a fluke with regard to grain production and prices in the U. S.? We do know the size of the crop was weather related, and more normal crops and lower prices are expected in future years. Will the consumer market recover? Yes, if the United States economy recovers. Will the backlog of beef in inventory be worked down? Yes, it is now in process. Where do we go from here?

The lessons we have learned are: 1) the U. S. consumer prefers young beef that is firm with a white fat and well marbled, 2) the market requires a uniform supply of uniform quality beef, 3) a large scale well coordinated feeding-slaughtering system is a highly efficient system, and 4) the U. S. can finish cattle rapidly and efficiently on grain. The beef industry that evolved during the 1960's met all these requirements.

Opportunities and Problems Confronting a Forage Fed Beef System

The U. S. is a sizeable market for processed beef. This is beef used for hamburger, weiners, bologna and other luncheon meats. Between 1964 and 1973, this market was supplied by cull cows, bulls and stags, and imported beef. The only requirement of this market is healthy bovine animals. The South has the potential to supply this market. The key is least cost production without regard to grade.

Cull cows, bulls and stags are by-products of cow-calf and dairy enterprises. Animals supplying meat for the processed products should be slaughtered in the areas where they originate. A considerable part of this type slaughter is boned out and shipped to processing plants in major consuming areas. Pork, imported meats and fat trim from block beef may be incorporated into the final processed products. In that the South contains a large part of the cow herd (both beef and dairy), the future of the region in this type beef is pretty much assured.

Major, but not insurmountable, problems arise in supplying the block beef market from forage feeding systems. Forages can be harvested and fed, or harvested by animals through grazing. Harvested forage requires more mechanical energy and labor per unit of weight gain on cattle than grain. Both the quantity and balance of nutrients necessary for high rates of gain are difficult to sustain for long periods of time on grazing systems.

A second major problem area is that of supplying the market with a uniform flow of uniform quality animals from forage systems. Nutrients contained in forages are not as concentrated nor as durable as they are in the form of grain. Slaughter animals from grazing systems result in bunched marketings near the end of the grazing season. On a large scale, this results in sharp breaks in price at the peak marketing periods. Moreover, a variable flow of variable quality animals results in an inefficient marketing system and dissatisfied consumers.

Requirements for a Successful Beef Industry

Relatively high grain prices that prevailed during 1974-75 may have misled people into believing that grain no longer has a place in cattle feeding. Grain is used for purposes other than cattle feeding. Weather related short supplies of grain caused the high prices not necessarily production cost.

The real challenge for research is to find the least-cost system of producing acceptable quality beef through a combination of forage (harvested and grazed) and grain.

The key inputs in the beef industry, as well as most other sectors, are energy and labor. Prior to 1973, energy was relatively inexpensive with high cost labor. Now and forevermore both energy and labor will be expensive. No longer can we afford to squander energy as we did in the 1950-72 era.

Much of the increase in the forage capacity of the South that occurred during the 1950-72 era came from an increasing use of energy -- mostly in the form of nitrogen fertilizers. A key challenge for future forage systems is to reduce the dependency on commercial nitrogen fertilizers. Obviously, this means incorporating more legume type plants in the forage systems.

Corn and alfalfa are still the king and queen in producing nutrients for cattle per unit of land where soil, climate and terrain are favorable. With the increased cost of nitrogen fertilizer, the advantage has probably shifted to alfalfa. We need to now reassess our position in terms of optimum use of energy and labor as well as land in producing beef. Harvested forage systems require more mechanical energy and labor than do grazed forage systems, but yield more beef per unit of land and applied plant nutrients.

Regardless of the source of nutrients, a successful beef system require rapid gains from weaning to slaughter weight and finish. Under most any system, gains on growing-fattening cattle of under 2 pounds per day will increase the cost of the end product.

In contrast, the cow-herd should be maintained on a near maintenance diet 8 to 9 months each year. This requires early weaning of calves. All crop residues (grain, soybeans, peanuts, etc.) and low quality pastures can be utilized for maintaining the cow herd.

Future Role of the South in the Beef Industry

The future role of the South lies not in a total forage beef system but in a system utilizing less grain than the traditional system that developed during the 1960-72 era. Under a predominately forage system, it would be economical to retain more calves through the growing-finishing period to slaughter. If so, cattle slaughter will increase in the region.

A program is needed to monitor and supplement the nutrients in forages (either harvested or grazed) in order to maintain rapid rates of gain. Most likely this would require some grain and protein supplement. Also, a short turn in a feedlot should be considered as a feasible alternative to slaughtering directly off a total forage system.

The South is rather variable in terms of soils, climate and terrain, and subsequently the seasonality and quality of forage. Slaughter facilities should be located to minimize the cost of assembling live cattle, slaughtering, and distributing the beef to consumer markets. This requires considerable detail on the potential location of slaughter cattle and time of marketing. Detailed data are available on location and size of consumer markets. To be competitive, the South must be efficient through all production and marketing activities. A second requirement is to deliver a uniform product on a continuous weekly schedule. This is not an easy order to fill with a predominately forage beef system. However, it can be accomplished with a high degree of coordination among research-educational institutions and all phases of the beef industry.

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SYMPOSIUM II: PANEL DISCUSSION OF FORAGE-FED BEEF

By Carl S. Hoveland 1/

Why Produce Forage Finished Beef?

The primary justification for beef cattle, when grain is in great demand for poultry, swine, and direct human consumption, is their ability to convert forages into high quality protein. Rapidly increasing world population, combined with crop failures in many areas of the world have in recent years made grain expensive. Even though grain prices have declined, long term energy prospects suggest that more forage will be utilized in the production of beef.

Predictions have been made that rising land prices and high grain prices will eliminate beef cattle from good crop land and shift them to land which may have rough topography or be otherwise undesirable for row crops. This has already occurred in many areas of the South. However, much land not well suited for crops can grow excellent pasture which can be used for finishing of beef cattle for slaughter.

Many countries in the world produce satisfactory slaughter beef on forage alone. Increased production of forage-finished slaughter beef in the southern USA is certainly possible when it becomes economically attractive to do so. I believe the southern USA will eventually develop large scale production of forage-finished beef. The big problem is making it an attractive opportunity for location of new slaughter facilities in areas where few or no such plants now exist. If grain prices are low, that day will be delayed.

Forage-finished beef must be profitable to the producers, the processor, and retailer. If forage-finished beef can be produced with low inputs of petroleum energy, then beef will be available at prices competitive with feed-lot beef. Actually, the feeding system used will not likely be entirely pasture or entirely feedlot but rather a mixture of the two, depending on consumer demand, availability of cattle, and cost of energy and grain.

How can We Produce Forage-Finished Beef?

Warm season perennial grasses such as bermuda and bahia are satisfactory for maintenance of brood cows but do not provide enough digestible energy for rapid growth of steers or heifers (Table 1). Daily gains of steers grazing Coastal bermuda or Pensacola bahiagrass do not usually gain much over one pound per day. In contrast, digestible energy and daily gains on dallisgrass are generally better although carrying capacity is lower than for bermuda or bahia.

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Slaughter grade of animals grazed on these warm season perennial grasses is usually only Standard or Utility. Steer performance on these grasses is much better when clover is present in the sward.

TABLE 1.--Digestible energy of grazed common southeastern USA pasture species and average daily gain of steers grazing them.

Forage	Digestible Energy, %	Average daily steer gain, lb.
Bermuda & Bahia	45-65	1.0
Dallisgrass	60-70	1.4
Tall Fescue	60-70	1.2
Pearl millet	65-75	1.1
Winter annuals	70-80	1.9
(Rye-ryegrass-Yuchi arrowleaf clover)		

Warm season annual grasses such as pearl millet and sorghum-sudan hybrids are high in digestible energy and have a high carrying capacity for short periods of time. However daily gains per steer are often no better than on perennial grasses. Tall fescue pasture during its main cool season growth period is fairly high in digestible energy and generally provides daily steer gains somewhat better than that obtained on warm season grasses. However, the toxicity potential with this grass can result in poor steer gains and finish. Animal performance is improved when ladino clover is grown in association with the grass.

Cool season annual pastures offer the greatest potential for producing forage-finished beef in the southeastern United States. Various combinations of small grains, ryegrass, and annual clovers can be used. These forages have a digestible energy concentration sufficient for cattle to reach a certain degree of finish. In the lower southeastern USA, a mixture of rye-ryegrass-Yuchi arrowleaf clover can be grazed continuously from November to June. Daily gains of about 2 pounds per day result in 400 pounds of annual gain per steer and slaughter grade of high Good to low Choice.

Some Problems in Producing Forage-Finished Beef

There are two major types of problems in the production of forage-finished beef: (1) pasture problems and (2) processing and marketing problems. Some of these problems can be alleviated with improved management while others will require further research.

Pasture Problems

(1) Winter annual pastures, especially on clay soils, can be seriously damaged by hooves of cattle grazing during wet periods in winter. Ryegrass forms a better sod than rye alone and can reduce pugging damage by cattle. However, animals may need to be removed from extremely wet pastures and fed stored roughage.

(2) Uneven seasonal distribution of forage production is a major problem when finishing steers on pasture. Unused forage accumulated during

a favorable growth period may result in overmature grass of lower nutritive quality and little or no initiation of new leaves. One way to overcome this problem is to stock the pastures at a rate to utilize forage during peak growth periods and supplement with corn silage during periods of insufficient pasture growth. Close grazing of winter annual pastures not only utilizes all the rye forage in late winter and early spring but also stimulates growth of high quality arrowleaf clover and ryegrass. If supplemental silage feeding is not possible, then pastures may need to be stocked less heavily and surplus forage during vigorous growth periods can be utilized by beef brood cows.

(3) Productive pasture legumes seem to be the key to maintaining good animal gains over a long season as well as reducing the cost of nitrogen fertilizer. Unfortunately, on many soils we do not have satisfactory adapted legumes. We are especially deficient in high quality, productive summer legumes that can grow in association with grasses. Much more research is needed in this area.

(4) Perennial grasses, especially warm season species, are too low in digestibile energy, resulting in poor gains and finish of growing animals. Breeding programs now in progress are making progress in developing more digestible grasses. Unless dependable cheap nitrogen is available from a compatible legume or symbiotically fixed in grass roots, large amounts of nitrogen fertilizer will have to be applied to these high quality perennial grasses. The same amount of nitrogen applied to corn grown on good cropland will produce more digestible nutrients per unit area.

Processing and Marketing Problems

(1) A major deterrent to wide acceptance of beef finished on pasture is that many of these cattle may have yellow fat. Cattle from these production systems are discredited at every level of the marketing system (whether justified or not) because of yellow pigmentation of external fat.

(2) Probably the most serious problem with developing a strong forage-finished beef industry is the undependable year around supply of slaughter animals. Winter annual forages are the only pasture species in the South that will permit cattle to reach a considerable degree of finish without supplemental grain feeding. Finishing cattle exclusively on winter annual pastures will result in an oversupply of slaughter animals in late spring and none over much of the year. A supply of slaughter animals at all seasons of the year is essential if this region is to support a significant slaughter beef industry.

SUMMARY

1. There is no easy way to produce a slaughter beef with suitable degree of finish year-around on pasture alone in the Southeast.
2. A successful forage-finished beef program <u>currently</u> must depend on:
   - (a) cheap land
   - (b) winter annual pasture
   - (c) legumes
   - (d) supplemental stored roughage (corn silage).

3. Future development of a forage-finished slaughter beef industry will require further research on:
   (a) Improved quality warm season grasses and legumes to permit a year-around supply of slaughter animals to processors.
   (b) Improved quality cool season perennial grasses and legumes with nematode and disease resistance.
   (c) Improved biological fixation of nitrogen by symbiotic bacteria on legumes and grasses.

SOUTHERN PASTURE FORAGE CROP IMPROVEMENT CONFERENCE
ANNUAL MEETING 1975

Overton Research Center, Texas A & M System
Overton, Texas

Discussion following panel concerning the production of beef on pasture

Mr. Harold Johnson: I would like to express my concern for research to develop a supplement that can be fed to cattle on pasture to change the color of the fat. Question by Dr. Glenn Burton: Can we convince the consumer that the yellow beef is just as good as yellow poultry meat? Dr. Maurice Ray responded that a good example to give was that the Coastal Bermuda dehydrates industry is interested in maintaining a high xanthophyl content in Coastal in order to enchance the shank color in poultry. Response by Dr. Joe Purcell: It does not seem to be as necessary to change the consumer as it is to change the standards so that the yellow fat is not discounted to the producer.

Mr. Bill Conrad: How long do you need to feed cattle in dry lot after cool-season grazing in order to get the yellow color out of the fat? Response by Dr. Aaron Baxter: Our research indicates that 49 days is not sufficient time in dry lot to get the yellow color out of the fat. Following Dr. Baxter's comment it was indicated that 60 days on dry lot would be necessary to get the yellow color out of the fat. Comment by Dr. Ray: There appears to be an area difference in the acceptability of yellow fat. Dr. Ray indicated that in his area of the country the packers did not discriminate against yellow colored fat. Dr. Ray emphasized that he was refering to tinted coloring in fat and not to the very deep color that can sometimes appear in older beef cattle.

Dr. Marvin Riewe commented that one chain store in his area was offering grass fed beef for 60¢ a pound less than they were charging for choice fed beef. Dr. Riewe interpreted this to mean that the marketing channel would be a greater influence on whether the cattle were moved to the feed lot off grass or directly to slaughter off grass. Dr. Joe Burns commented: It may not be too important whether the beef is yellow or white, but more importantly whether the consumer has income to purchase beef. It was emphasized that the total profit chain is important and must be considered with respect to how efficiently beef can be merchandised. Response by Dr. Purcell: The developments in price between low, good and choice steer carcasses is $11 per hundred weight. This means that the final 200 pounds on a steer is worth $90 per hundred weight. Thus, presently it is paying to finish cattle to choice grade.

Dr. Tim Taylor: My question is to Dr. Ray. Is the quality of beef affected by preslaughter stress? What is preslaughter stress? Response by Dr. Ray: Preslaughter stress represents that stress to that animal inducted in the hauling and other manipulation of the animal and its carcass during the killing and dressing operation. It is usually the kind of handling the animal is

subjected to immediately before it gets to the packer. The management of the animal immediately before slaughter has much to do with the color of the red meat in the dressed carcass.

A question with respect to Prime and choice beef from grass and grain, would there be a difference in quality? Response by Dr. Ray: There would be no difference.

Would the amount of yellow color in the carcass depend upon when the cattle were pulled off pasture? Response by Dr. Ray: Our cattle discussed above came off pasture in early June. A further comment was made that some data show that cattle coming off wheat pasture in March did not carry fat pigmentation. Based upon this finding it may be that we should select the proper time of removing cattle from pasture to slaughter. Another comment was made that the fat is trimmed off carcasses and, therefore, fat color is of little importance.

Mr. Bill Smith: Is there an opportunity for mechanical tenderization to improve froage fed beef? Response by Dr. Ray: Some work from Texas A & M University indicates that the way the carcass is hung in the cooler may affect the tenderness of the carcass. Dr. Ray emphasized that anything we do to the carcass adds to the cost and this cost must be justified in improvement in the carcass.

Dr. Ethan Holt observed that the consumer reaction recently stopped legislation concerning a change in the meat grading system. He suggested that the action of consumer groups is an important influence on market systems and we must recognize this influential factor in our beef production system. Dr. Holt emphasized that we should develop forage grazing systems in order to maintain good distribution of forage throughout the year and thus be able to produce quality cattle off pasture. Dr. Holt also emphasized that there was need to develop quality into warm-season perennials so that these crops could be used in sequence with cool-season annual pastures. He indicated that more research was needed in this area. Dr. Carl Hoveland commented that we must seek major improvement in the performance of animals on warm-season perennials. He emphasized that we must manage cattle for rapid growth rate. Because of the high interest cost for money invested that we can not extend the period of time that we keep cattle on pasture. Dr. Hoveland was asked how we might get this increase rate of gain on warm-season perennial pastures. His response was that he did not know, but perhaps Dr. Glenn Burton would like to comment on this subject. Dr. Burton responded that perhaps a legume might be one way to improve cool-season annuals. However, there are serious limitations in legumes with respect to disease and climatic variables. Certainly more research in needed in this area.

Question by Dr. Ray: I would like to ask if there is any prospect for an alfalfa that can be produced in pastures? Response by Dr. Burton: In Florida there seems to be nice progress in developing an improved alfalfa. There is the problem of seed production in alfalfa; also there are serious disease problems. Dr. Burton said that he did not think that we have to have a legume in order to get quality in warm-season perennial forages. He stated that management is an important factor in maintaining high quality in forage. Dr. Burton cited the example of improving sorghum quality by selecting to remove the gloom. This work was reported in Crop Science; this simple gene change makes a lot of difference in the nutritive value of Sudan grass. The increase of digestibility amounted to 22%. This compares with a 12% improvement in digestibility for Coast-cross Bermuda over Coassal Bermuda. This 22% increase was reflected in a 30% increase in beef production.

Dr. Baxter: I would like to ask Mr. Johnson what he plans to do this fall and winter with his grazing program? Mr. Johnson: I am going to increase; I will buy some steers and I will be buying larger steers to put in a pasture by themselves. I believe I can increase my grazing program to improve efficiency in use of my land, machinery, and time. This program doesn't tie a manager down. It permits time to go fishing. Thus, there is great convenience in carrying out this grazing program.

Dr. Horn: My comment is relative to the international market for high quality beef. Are we going to have a turnaround and must we write off our export beef market? Do we need legislative protection? Response by Dr. Purcell: The United States is the largest producer of beef and also the largest importer of beef. Dr. Purcell emphasized that we have a large requirement in this courntry for processed beef and about 30% of this is imported. New Zealand, Australia and Argentina have some advantage in producing processed beef and that is particularly because we have a land use requirement in this country. In the Southeast there are opportunities for producing processed beef in contrast to block beef. Marvin Riewe: If we go for processed beef production can we compete with imports or do we need legislation to block the imports for us to get into that? Response by Dr. Purcell: No, we do not have to have regulations. However, there is a contradiction in our import/export laws. These need to be modified.

Question by Dr. Burton: Relative economics of the baby beef production as compared with carrying the calf on to heavier weights. Does the industry have to go past the baby beef stage in order to be profitable. Response by Dr. Purcell: For the short term we are going to slaughter the 600 pound calves. Beyond this short period we have too much cost into the cow/calf. In order to market the calf, then we must carry the calf on to about 1000 pounds slaughter weight. Minimal cost of beef comes from about a 1000 pound animal. It was suggested that the animals need to be grown past weaning.

Question had to do with the relationship of stocking rate to beef production per acre. The question seems to be "Why do you graze the pastures short?" Response by Dr. Hoveland: We graze short to maintain the legume in the sword and nutritional quality of the sword. Reference was made to Mr. Johnson's statement that cattle standing in belly-deep forage did not gain as well as those on short forage. When the sword growth gets out of hand, daily gain drops. It is a complicated thing; less clover in the pasture with more mature leaves causes quality of forage to drop.

Question by Dr. Hagen Lippke: Referring to the data presented by Dr. McCarter, at what point on the forage production curve would we maximize beef production? Response by Dr. Hoveland: "The eye of the master fattens the beast." We should adhere to this philosophical concept. Response by Dr. McCarter: Management of the grasses is important and should be related to the management of the legumes. There was further discussion in this area by Drs. McCarter, Hoveland, and Lippke. There comments were primarily stimulated by the information presented by Dr. McCarter in his paper. Not all the comments made at this point were recorded; one interested in this discussion should refer to the paper by Dr. McCarter, especially the graph showing the relationship of forage availability and animal performance.

Dr. McCarter cited some data from Dr. Burton where cattle had made an average daily gain of two pounds on Coastal Bermuda at the Homer, Louisiana Station. It was stressed that one could get this kind of gain on steers on Coastal Bermuda where the sword and cattle were properly managed. Dr. Riewe commented that forage availability was an important consideration.

Question by Charlie Welch: In the short run we are depending upon a cow/calf production for beef, and I am wondering if we are doing any work to enhance the milk production of the cow. Dr. Maurice Ray: Yes, much effort is being put forth to improve the production of the beef cow. As an example, we are using the beef-dairy crosses to enhance milk production.

Comment by Dr. McCarter: It is necessary to give attention to the region when one is selecting the kind of livestock to use. There are differences in animals in respect to geographical areas. Dr. McCarter commented that cattle do selectively graze and may use only about 50% of the forage available. Comment by Dr. Lucas: With respect to Dr. McCarter's diagram, the grazing results would depend upon whether the sword represents one specie or several species. As an example, grazing pressure might need to be regulated to preserve legume in the sword. Dr. Lucas also stated that in grazing tests on Coastal Bermuda, changing the grazing pressure on the sword to keep the grass short and vegetative increased the ADG from about 1.3 to 2 pounds. Thus, the management of the animals and the sword has much to do with the animal performance results one should expect.

Question by Dr. Ethan Holt to Dr. McCarter: Could you comment concerning the expected performance of yearling cattle that were placed to graze warm-season perennials after a grazing period on cool-season annuals? Dr. McCarter responded by emphasizing that there would be a difference with respect to whether the calves were spring born or fall born. For spring born calves there would be little delay between weaning and the time the animals could be placed to graze cool-season annuals. In contrast, fall born calves would be weaned from their dams much earlier than they could be placed to graze cool-season annuals. Question by Dr. Homer Wells: If we want to eat beef the year round, why do we have to have our calves born at a particular segment of the year? Response by Dr. Ray: Although for good management we plan our calving program accurately, we have calves available throughout the year. Comment by Dr. Riewe which was not audible on the tape.

Comment by Dr. Pratt: Here in the Southeast we can grow forage almost 365 days of the year. It is important that we give our attention to developing forage management systems that fit our various regional areas and that make full use of our great potential for the production of forages. Dr. Riewe: As researchers, it is our responsibility to develop systems of producing beef that are efficient and that utilize our potential for feed production.

FORAGE RESEARCH IN THE SOUTHERN REGION: OBJECTIVES, EMPHASIS, AND TRENDS

By A. W. Cooper[1/]

It is a pleasure for me to be with you today at this most important Forage Breeders Work Group.

House Resolution 1339 states in part:

> "as a prudent nation, we make immediate and substantial public investments in agriculture research and technology for the purpose of increasing food production."

Secretary of State Kissinger said, before the U.N. General Assembly, that "international, national, and regional research programs must be expanded. Scientific and technical resources must be mobilized now to meet the demands of the year 2000 and beyond."

That sounds like agricultural research is basking in a warm, comfortable climate. With our present staffing and funding, we cannot consider these as halcyon days, however. Since 1971 the ARS budget has declined about 27% in constant dollars. There are 200 fewer scientists in State Agricultural Experiment Stations than in 1966. But we should consider the House bill and Secretary Kissinger's statement as a charge and a challenge.

As I've said many times, we do have the resources--the people, the water, and the land--to accept the charge and meet the challenge for a plentiful supply of food and fiber. We must do the best we can with the research funds available to

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obtain the technology needed as conditions change. Work groups such as this one can be a catalyst to improve forage production in the South and to contribute to the technology needed to improve the economics of the Southern Region of the United States.

Grass-producing lands cover about one half of the area of the world. These lands protect the environment from erosion, they beautify, and they produce feed. Forage is one of our most important crop commodities, and we need to increase our knowledge about its cultivation.

There were more than 21 million acres of unused land in the Southern Region in 1966 that offered great opportunity to expand the livestock industry. No doubt some of this land has been put back into crop production. However, large numbers of acres still remaining idle could be best utilized for forage production. Much land is now underutilized.

Cattle are well distributed in the Southern Region. Texas and Oklahoma have the largest number of beef cattle, and North and South Carolina have relatively few. The largest concentration of dairy cows in the Southern Region is in Texas, Kentucky, Tennessee, and Florida. We should increase the population of other ruminant animals in the Southeast.

Preliminary figures by the Statistical Reporting Service show that the cattle and calf population in the Southern Region in 1974 was 44.8 million, up 2.6 million over 1973. This adds up to a total farm value in the 13 Southern States of over 12.5 billion dollars. That represents 30% of the total in the United States. Research shows that many areas in the South have the capacity to produce large quantities of a variety of forages to support these animals. However, these forages vary greatly in their concentration of digestible nutrients, and there are great differences in animal response to grazing on the wide variety of species that can be grown.

Grasses and legumes, which can be produced on land not well suited for crops, contribute significantly to man's food supply when processed through ruminant animals. Forage-produced beef contains less fat and may be more nutritious than grain-fed beef. In many areas of the Southern Region, beef could be produced--and marketed at a lower cost--on pasture, with little or no grain feeding. In Puerto Rico, milk can be produced successfully on an all grass ration. The South has a greater potential for feed production than any other section of the United States, which suggests a need for more research aimed toward selection of better production systems.

Many ARS scientists have told me that their research program could not be carried out effectively without the cooper-

ation they receive from the States. I hope that the cooperation is a two-way street.

Forages in the South must be integrated with the most highly diversified agriculture in the United States. Few farmers in the South are interested only in livestock. Therefore, livestock and the forages needed to feed them compete with cash crops for land, labor, and equipment. Far too often cash crops receive priority. Last March, I met with the Southern Regional Planning Committee. During the meeting we were pleased to hear from Dr. Ray Corkern, an ERS economist stationed at our Southern Regional Research Center in New Orleans. Ray presented some interesting statistics. I'd like to review a few with you.

The per acre yield of silage in the Southern Region is not quite 92% of the national per acre yield. Hay yield is just over 84% of the national yield. The Southern Region accounts for 35.2% of all cattle and calves in the U.S., yet the Region receives only 30% of the total dollar value. One reason for this low percentage is the fact that southern farmers and producers sell their calves at an early lightweight age. The Southern Region is a net exporter of cattle, and the North Central and Western Regions are net importers.

If we concentrate on beef cattle alone for a moment, the Southern Region has 46% of the total U.S. beef-cow population, that is, beef cows that have calved, or a total of 22 million head.

Dr. Will Butts, Technical Advisor for beef cattle, tells me it would be advantageous to hold calves to about 700 pounds-- called in the industry a "handy weight feeder"-- rather than selling weaned calves weighing 450 pounds. If you disregard last year's market, it can mean 20 to 25% more weight to producers over a long period of time. This production practice could mean considerable savings in grain.

Percentages are about the same today as in 1970, when the Southern Region accounted for just over 27% of the total U.S. population. However, the Region accounted for 40% of the total farm population, showing that the highest ratio of farmers to population is in the South.

The Southern Region has more resources and practical alternatives to provide year-round feed production than any other section of the United States. Does this fact tell us that we should be directing more research toward selection of better production systems? I think it does and I think we are.

ARS is conducting forage research in every Region. The Southern Region has several locations involved in increased forage production.

At College Station, Tex., there are 4 ARS scientists developing technology to improve the productive capacity and nutritive value of range ecosystems for cattle and sheep and for coordinated multiple use. The direction being taken is with ecological and physiological studies in plant communities. They're concerned with improving varieties and practices for more efficient forage-livestock ecosystems. This work is aimed at reducing livestock production costs and to conserve natural resources.

Research by 4 ARS scientists at Raleigh, N.C., is devoted to improving production practices and performance of forage varieties. They are developing grasses and legumes with higher yield and quality, and with resistance to diseases, nematodes, insects, and environmental stresses. They are investigating new cultural practices and utilization of forages for hay, silage, or pasture to reduce the cost of feed for producing livestock products.

At Tifton, Ga., 5 ARS scientists are studying the cytology, genetics, breeding, pathology, and quality of several forage grasses, legumes, and turf grasses adapted to the Southeastern U.S. They work cooperatively with State and Federal plant and animal scientists and utilize the information obtained to develop improved varieties and germplasm sources. Improving forage quality by breeding and management is being emphasized to increase the efficiency of red meat production. Coastcross-1 bermudagrass, capable of increasing average daily gains and liveweight gains per acre by one-third, is the first varietal product of this research.

At Tifton, Ga., our scientists are striving to improve equipment to manage forages, to find improved methods and equipment to increase the drying rate of forage, and to develop utilization of solar energy to replace some of the fossil fuel required for mechanical drying. Other objectives at Tifton are packaging, handling, transporting, storing, and feeding of hay and silage. Research is also being conducted to improve the digestability of forage crops.

There is other research at Tifton that I would also like to mention. One is the important work to develop safer, more effective chemical methods for controlling insects on forages and legumes, which parallels the research on cultural and management practices to reduce insect populations. Another area is the search for, and the research on, parasites, predators, and insect pathogens for possible use as control agents. The whole idea is to utilize new and radically different insect control methods and mold them into suitable and efficient pest management systems.

At Mississippi State, the objectives of one ARS scientist include improving grass and legume seed efficiency for producing forage, pasture, range, and turf. He wants to assure that domestic and foreign markets have recurring supplies of high-quality seed of improved varieties.

There are 8 ARS scientists at Athens, Ga., working on forage research, developing improved methods for feeding dairy cattle. The emphasis is on production and storage of high quality forage. Scientists are also evaluating the efficiency of pelleted forages.

In addition, there is one ARS scientist at Temple, Tex., working on development of new varieties of weeping lovegrass having improved forage quality, winter survival, drought tolerance, and seed production.

One ARS scientist at Woodward, Okla., devotes his efforts to developing range improvement tools, improved annual and perennial pastures, and ranching practices for increased quality and quantity of forage.

The objective of the ARS scientist at Stillwater, Okla., is to develop efficient cultural and management practices to provide maximum reproductive potential of bermudagrass, weeping lovegrass, switchgrass, and other introduced and improved native grasses.

At Poplarville, Miss., one ARS scientist cooperates with MAFES scientists on basic research on forages, including measurement of regrowth potential, quality, and yield of perennial grasses in relation to animal performance.

An ARS scientist at Clemson, S.C., studies methods to increase longevity of white clover stands and improved distribution of forage production by breeding varieties with heat and drought tolerance, improved resistance to pests, and improved persistence.

Studies on forage plants for use in maintaining a vegetative cover and for providing a potential for economical use of surface mine spoils is the emphasis of one ARS scientist at Blacksburg, Va.

Two ARS scientists at Lexington, Ky., direct their work toward development of superior varieties of tall fescue with high nutritive value, palatability, disease resistance, and yield.

One ARS scientist at Gainesville, Fla., is studying the specific biochemical processes affected in forage species when

growth is adversely affected by environmental stresses. ARS, in cooperation with University of Florida scientists, has recently placed emphasis on exploring the possibility of nitrogen fixation in tropical grasses.

Not all of the scientists mentioned are able to devote full time to forage-research problems, but ARS participation in forage work in the Southern Region involves approximately 32 scientific man years.

This is just a brief summary of the broad areas of research going on in ARS in the Southern Region. Our colleagues in the other Regions are also working to reinforce the overall effort to improve the production, efficiency, and utilization of forages.

Forage research is difficult, time consuming, and expensive. Cereal research is concerned with one harvest a year of a reasonably uniform product. On the other hand, forage research requires many harvests per year of a highly variable product. Forages have all (and perhaps more) of the pest problems of the cereals, plus the additional problems of seed production.

In addition to the emphasis and objectives in forage research, I've been asked to touch upon the trends; I presume this means future needs.

Heretofore, most research focused on component parts of the milk or forage-beef production systems. In the future we need to focus not only on the behavior of individual system components but also on the mechanisms whereby the components are coupled with each other, for example, the interfacing of sward and animal. Thus, we need to emphasize a fully integrated, interdisciplinary approach to forage-animal production problems.

Several areas of forage research that will receive special attention are--

Collection, evaluation, and preservation of forage species to provide germplasm for improving forage crops.

Breeding of warm- and cool-season forage species for superior nutritive value and improved persistence.

Development of equipment and techniques for improving the establishment and management of small-seeded grass and legumes.

Identification of the extent of stand, yield, and nutritive losses from weeds, insects, diseases, and other pests and the development of new and improved chemical, biological, and cultural methods to control these pests.

Development of technology for improved establishment of symbiotic relationship.

Rhizobia strain evaluation for tolerance to high temperatures and acid soils.

Development of forage systems for meat and milk production.

Evaluation of promising components of crossbred cow-calf test units, development of better breeding methods, and breeding of cattle that will better utilize forages rather than concentrates.

And finally, in relation to cool season grasses, development of a creeping winter grass for the coastal plains similar to the bluegrass that is so effective in the limestone soils.

Those are just some of the challenges that are ahead. As we look into the next 3 to 5 years and further, it seems obvious that even greater demands will be placed on our land resources for the production of food and grain crops which will mean less acreage for livestock and forages. This inevitability does not mean, however, that our need for forages will decrease. The dairyman who is making a profit today has a feeding program based soundly on stored forages: silage, haylege, or hay. The cattleman, to stay in business, must rely heavily on grazing for beef production. The demand for meat and milk will remain strong. The beef and dairy industries of the future will be based more squarely upon the feeding of forages than they do today, a result of the high cost of grain and protein supplements. Pressures on land resources will mean that American farmers will have to do a better job of producing forages. Higher production per acre is needed, and lower cost per unit of feed is essential.

When you and your colleagues have accomplished these goals you will have solved critical economic problems facing the South while helping to meet the food needs of the world.

I wish you a most successful meeting.

A REGIONAL APPROACH TO BREEDING FORAGE CROPS

By J. E. Halpin [1]

INTRODUCTION

The four key words provided are advantages, disadvantages, limitations, and mechanics. Disadvantages and limitations would be closely related. Let us proceed to consider the negative first and then proceed to the more positive aspects of the topic.

If the scientist prefers to build an "Ivory Tower" image around himself then regional research is not the answer. One might paraphrase this by saying, "I prefer to be here by myself, although I may be in the dark." In today's world, this makes about as much sense as a person trying to cover up the fact that he has Syphillis. Another way of looking at it is that if you cooperate, someone may find out about your limitations. Certainly we would not want that to happen. At the same time, the will and forcefulness of others may affect your work, either its direction or its load. People may question your selection of projects and priorities, even your approaches. The results could be that your pet project does not receive the acclaim that you had hoped for and instead of getting comfortable in science, a degree of professional discomfort might result. Enough for the negative.

Turning to the advantages of the regional effort we must keep in mind that forage crops are diverse in habit, characteristics, problems, and purposes. Nonetheless, in the philosophical vein there are certain advantages which must be considered.

The famous Pound Report noted that in agricultural research, the regional research program of the state stations had provided more publications per SY of time than any segment in the public agricultural area. This might be the result of the second advantage I have for you: social. The very fact that the regional research program involves cooperation with others, often from different disciplines and certainly different environments, provides an impetus which may not be available in other climes. Likewise as different disciplines come together, each brings its own "laws" or "modes of operating" which have built up over the years and may not be totally valid. Thus a check and balance system might be provided for the conscientious investigator who desires to take advantage of the system.

There is one area in limitations which is unique and deserves separate understanding: that of funding. It is correct that under the Hatch Act, certain of the funds appropriated thereunder are earmarked for regional research. However, this does not guarantee that participating in a regional research project will mean necessarily extra funds become available to the investigator.

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Levels of current funding for regional research projects in general indicates that much more non-regional Hatch and even more state appropriated funds are placed on the regional research program by the station directors than the law requires. As a result, it is possible that for an individual scientist, involvement in a regional research project may only result in a change in funding source, not actual funding level. However, experience has shown that often times development of regional research projects can result in renewed attention to a project area and the administration of funds providing extra increments of dollars as means of supporting the concepts which the scientists collectively are undertaking.

The mechanics of establishing a regional research project are straight forward and spelled out in a publication by the Cooperative State Research Service entitled, "Manual of Procedures for Cooperative Regional Research." Incidentally, this manual is currently undergoing revision but the bulk of its contents are quite well established.

Assuming that a group of scientists have reason or belief that a regional research project might be developed, they can follow the various steps in the manual and although it appears to be an administrative hassle to do so, actually the effort involving the initiation of a project is not that great.

To initiate a topic, a letter to a station director providing a paragraph on concept and need can result in his initiating, through SRRC, a recommendation for an area of work. Once an area of work has been approved, steps in establishing a regional research project can follow. To do so is certainly not "Ivory Tower" but truly positive, in spirit and action.

SIGNIFICANT ADVANCES IN PLANT TISSUE AND CELL CULTURE

By Earlene A. Rupert [1/]

The usefulness of cell and tissue culture in plant improvement was proposed by Haberlandt as early as 1902 (14), but significant progress was delayed for several decades by the absence of biochemical parameters for the nutritive and physical environments in which isolated cells and tissues could survive and reproduce. The urgent need to equalize the relationship between population growth and food supply has inspired recent intensive collaboration among basic and applied physiologists, biochemists, molecular geneticists and plant breeders in this new area of genetic engineering. Excellent and detailed reviews of their accomplishments and the application of these to agricultural problems have been published between 1972 and 1975 (1, 3, 12, 17, 21, 23, 29, 30, 31).

Most living tissues can be excised and cultured. Many, such as embryonic tissue, apical meristem and leaf mesophyll, are capable of expressing the complete range of genetic information found in a zygote. General *in vitro* culture techniques for higher plant tissues were developed by Phillip White during the middle decades of this century and are summarized in his classic manual (32). Since the discovery of auxins, cytokinins and gibberellins in the fifth and sixth decades, cultures have been stimulated to regenerate new plants, although, frustratingly, each species, often each variety, seems to require a different combination of mineral salts, sugars and growth regulators. During the last five years, enzymatic removal of the pecto-cellulose cell wall has produced a membrane-bound protoplast capable of incorporating plastids, bacteria, viruses, exogenous DNA and polystyrene balls, and also capable of fusing with related and unrelated neighbors to form "somatic hybrids" (30). Higher plant biologists need envy the facile transformations of species reported by the microbial geneticists no longer!

Meristem culture

Plant reproduction through meristem culture already is a common and highly profitable practice among nurserymen specializing in horticultural species such as orchids, carnations, and chrysanthemums. Stem apices retain their organogenetic potentiality until the flowering process is initiated. Morel and Wetmore (22) first grew fern apices on mineral salts and sugar water in 1949, but had little success with other species (sunflower, dahlia, potatoes) until gibberellins and potassium were found to stimulate apical organogenesis. In 1964 Morel (20) extended the technique to orchids, whose meristem, on an agar-based medium, produces numerous embryo-like protocorms, each of which can be

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subdivided ad infinitum to produce plants identical to the original stock. Some 22 orchid genera are propagated currently from shoots, leaf tips and young inflorescences (23).

Murashige (23) has listed 151 species and varieties distributed among 54 additional plant families with demonstrated potential for clonal multiplication through meristem tissue culture. Chrysanthemums are a striking example of the efficiency of shoot meristem culture. Reproduction through conventional cuttings may give 30,000 6-inch plants in one year; reproduction via shoot culture on synthetic media can give 9 million; via shoot-callus-cell culture the number can be increased to 90 billion in the same time span (10, 11). Moreover, four-year-old cultures continue to produce normal plants. The multiplication of hybrids has been especially profitable: An F_1 hybrid asparagus derived from crossing diploidized haploid lines has been multiplied and distributed by Morel (21).

Careful removal of differentiated tissue surrounding the meristem has produced virus-free lines of those above and many other species, i.e., strawberries, geraniums, dahlias, potatoes, and white clover.

Foresters recognize that these new procedures may ease their struggle with the long life spans of trees and are actively developing culture media for species and hybrids.

There is no doubt that many of our forage crops can be manipulated to advantage in similar fashion once the specific culture conditions have been defined.

Callus and cell suspension cultures

Callus and cell suspension cultures are easily obtained from hypocotyl, pith, endosperm, meristem and other tissues, and may be maintained in active reproductive condition for many years by replenishment of nutritive substances. However, with a few exceptions such as the model plants carrot, tobacco and sugarcane, the embryogenic capacity of these cultures deteriorates rapidly and they have not proved especially useful yet in clonal multiplication (23). Cultures of sugarcane, in which organogenesis seems to be an endogenous capacity, have been the source of several new cultivars from pith and inflorescence. These vary in genotype and chromosome number from the parental clones. Resistance to leaf scale and eyespot has been isolated from cane cells treated with gamma irradiation (16, 18, 25). Similar intrinsic variability and regenerative capacity have been well-documented for tobacco.

Considerable commercial interest has developed in the use of chemostatically maintained cell suspensions as a means of mass production of physiologically active substances such as the anti-cancer drug campothecin from *Campotheca*, virus inhibitors from *Phytolacca*, napthoquinone pigments from *Lithospermum* (19), and insulin from *Mormordica*. Regulation of the production of these compounds through tissue selection and substrate fromulation has been proposed.

Anther culture

The development of haploid plants from agar-cultured post-meiotic anthers of *Datura innoxia* was first reported by Guha and Maheshwari in 1964 (13). In a similar manner, Nitsch and Nitsch (26) obtained large populations of haploid tobacco plants from which homozygous diploids were obtained by both natural and colchicine doubling. Recently, Sunderland (31) listed 12 crops species for which anther culture has been from 1-100% successful (Table 1); 5 of these

belong to the family Solanaceae, 4 are cereals and most fall near the 1% production level. Apparently, the anthers of few species contain the regenerative capacity of tobacco and perfection of culture techniques may be painfully slow.

TABLE 1.--Haploid plants from anthers or pollen

Order	Family	Genus	Species
DICOTS			
Rhoeadales	Cruciferae	Brassica	oleraceae and x alboglabra
		Arabidopsis	thaliana
Geraniales	Geraniaceae	Pelargonium	hortorum
Tubiflorae	Solanaceae	Atropa	belladonna
		Lycopersicon	esculentum
			pimpinellifolium
		Capsicum	annuum
		Datura	innoxia
			metel
			meteloides
		Nicotiana	tabacum
			et al.
MONOCOTS			
Graminiales	Gramineae	Oryza	sativa
		Lolium	multiflorum
		Lolium	L. multiflorum (4x)
		x Festuca	x F. arundinaceae (12x)
		Hordeum	vulgare
		Triticum	aestivum
		Triticale	
		Aegilops	caudata x umbellulata
		Setaria	italica
Liliales	Liliaceae	Lilium	longiflorum

From: Smith, H. H. 1974. Bioscience 24: 269-276.

However, the time-saving offered plant breeders, particularly those working with long juvenile periods, by the immediate production of true-breeding offspring from F_1 hybrids, would be of great value (29).

Kasha (17) has used successfully a different haploid technique in breeding barley. F_1 hybrids of Hordeum vulgare varieties are stimulated to produce haploid embryos by pollination with H. bulbosum, a perennial species. Embryos are cultured in the laboratory, treated with colchicine, and the resultant homozygous diploid lines are field-tested without concern for further segregation. Varieties are ready for release three years after the initial cross.

Protoplast culture, fusion, and transformation

Manipulation of the nuclear and cytoplasmic organelles of higher plants has been impeded until recently by the structural characteristics of the cell wall. Since Cocking's first release of living naked protoplasts after enzymatic digestion of the walls of tomato root tips (6), protoplasts have been obtained from fruit, leaves, roots, root nodules, endosperm, flower petals, tubers and other organs of many species (1). Transformations and insertions of nuclear and cytoplasmic organelles and fusions of somatic cells are no longer unusual.

Somatic hybridization of cultured mouse cells was observed by Barski et al. in 1960 (2), and of man with mouse cells by Harris and Watkins in 1965 (15). Intra- and interspecific plant cell fusions were reported first between corn and oat root-tip protoplasts after treatment of mixtures with sodium nitrate in sucrose solution (28) in 1970. Many researchers since have obtained fusions among closely and distantly related species (Table 2) (1, 12). Among these are soybean fused with barley, corn, pea, rape, and alfalfa. Sodium nitrate has been replaced by a more effective aggregator, polyethylene glycol.

That hybrids can be regenerated from fused protoplasts was demonstrated elegantly by Carlson et al. (5) with a "parasexual" hybrid between *Nicotiana glauca* and *N. langsdorfii*. Leaf mesophyll protoplasts from complementary nutritionally dependent strains were fused to produce a hybrid. Protoplasts were plated onto a medium inadequate for the survival of cells of either parent. Plants obtained from fused cells were identical with interspecific hybrids obtained by traditional cross-pollinations.

Extensive development of wide new hybrids from protoplast fusion undoubtedly will be limited by the nature of interspecific differences and will probably provide little competition for traditional methods of hybridization. In addition, development of fusion hybrids is limited presently by the lack of selective media for elimination of non-fused cells, by the lack of methods for regeneration of whole plants, and by the rarity of nuclear fusion itself after cell fusion (Table 3).

In 1969 Nass (24) reported the incorporation of spinach chloroplasts into animal cells where they retained their identity and divided normally, demonstrating the autonomy of these plastids--and giving rise to facetious speculations by the press on the creation of photosynthetic animals. Carlson (3, 4) inserted normal chloroplasts into albino tobacco protoplasts where they continue to function and reproduce, suggesting possibilities for introducing improved photosynthetic pathways into many of our crop plants.

Protoplasts will incorporate various other foreign substances by invagination of the plasmalemma during cell wall removal. Included are viruses, bacteria, and exogenous DNA. Precise studies of infection, gene complementation and enzymatic action have been faciliated by protoplast availability. Exogenous DNA, however, is usually degraded rapidly by nucleases and currently reported permanent effects on plant development are still questionable.

Incorporation of *Rhizobium* and *Agrobacterium* into protoplasts has had repeated success, but as yet no new symbionts have been regenerated. Legume root-nodule protoplasts containing packets of bacteria have been extracted by Davey et al. (7, 8) and progress made in inducing their fusion with non-legume protoplasts (27). Effectiveness of new associations can be tested by acetylene-ethylene reduction during culture on a nitrogen-free medium.

TABLE 2.--Intergeneric plant protoplast fusion and heterokaryocyte division

SOURCE OF PROTOPLASTS		
Leaf mesophyll		Cell culture
Barley (*Hordeum vulgare*)	X	soybean (*Glycine max*)
Pea (*Pisum sativum*)	X	*Vicia hajastana*
Corn (*Zea mays*)	X	soybean (*Glycine max*)
Pea (*Pisum sativum*)	X	soybean (*Glycine max*)
Rapeseed (*Brassica napus*)	X	soybean (*Glycine max*)
Alfalfa (*Medicago sativa*)	X	soybean (*Glycine max*)
Sweet clover (*Melilotus alba*)	X	soybean (*Glycine max*)
Chick pea (*Cicer arietinum*)	X	soybean (*Glycine max*)
Angelica archangelica	X	carrot (*Daucus carota*)

From: Gamborg, O. L., et al. 1974. Can. J. Genet. Cytol. 16: 737-750.

TABLE 3.--Examples of protoplasts in which cell regeneration and division has been observed

Systematic	Common Name	Cell Origin
Ammi visnaga (L.) Lam		culture
Bromus inermis Leyss.	Brome grass	culture
Cicer arietinum L.	Chick pea	leaf
Brassica napus L.	Rapeseed	culture, leaf
Daucus carota L.	Carrot	culture, leaf
Glycine max (1) Merr.	Soybean	culture
Linum usitatissimum L.	Flax	leaf
Medicago sativa L.	Alfalfa	leaf, culture
Melilotus alba Desr.	Sweet clover	leaf
Phaseolus vulgaris L.	Bean	leaf, culture
Pisum sativum L.	Pea	leaf
Pisum sativum L.	Pea	culture, shoot tip
Vicia hajastana Grossh.		culture
Vigna sinensis L.	Cow pea	leaf

From: Gamborg, O. L., et al. 1974. Can. J. Genet. 16: 737-750.

In addition to new symbiotic relationships, there is the possibility of cryptic transfer of the nitrogen-fixing operon to new species by means of transducing bacteriophages. Apparently, Doy et al. (9) already have been able to transfer the galactose operon from *Escherichia coli* to haploid *Lycopersicon* and *Arabidopsis* callus by means of a bacteriophage. They have coined a new term, "transgenosis", to describe the event. One can visualize a combination of genes from *Rhizobium*, *Azotobacter*, mycorrhizal fungi and blue-green algae which, as either plasmid-like symbionts or structural components of the plant

genome, might go far toward liberating agriculture from the expense of applied fertilizers.

The preservation of germplasm through liquid nitrogen freezing of protoplasts or cell cultures is of considerable potential importance. Periodic costly replacement of banked material through seeding or vegetative propagation with the inevitable loss of genetic variability to disease and weather might be avoided. Normal plants have been obtained from carrot and other species which have resumed mitotic activity after prolonged freezing. The use of these microbiologically sterile tissue cultures in plant introduction may revolutionize our quarantine limitations. At the same time they promise safe and efficient means of maintaining while containing cultures of infectious organisms such as viruses and nematodes.

Plant breeding can be aided enormously time-wise and space-wise by laboratory techniques allowing for early screening for photosynthetic pathways, heterotic combinations, resistance to pest toxins, protein synthesis, etc. Chromosomal and genetic variability is characteristic of many kinds of cell and callus cultures; regeneration from single cells with or without the use of mutagens would allow economical study of and selection among variants on a large scale and might facilitate recovery of diversity lost during past ages of selection. Use of haploid cultures in these experiments would avoid lengthy selection against recessive lethals.

In summary, it is clear that spectacular advances in the areas of plant improvement and plant growth in the near future may be achieved by manipulation of cultured plant cells and tissues through the processes of reproduction, fusion and regeneration, and by accessory studies of physiological activities at the cellular level. Regeneration of whole plants from cultured cells is the major remaining unsurmounted barrier to realization of an infinite potential contribution to agriculture.

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EXPLORATION AND COLLECTION OF PASPALUM SPECIES IN SOUTH AMERICA

By Byron L. Burson [1/]

In November 1974 Dr. W. R. Langford [2/] and I were asked by the United States Department of Agriculture to travel to South America for the purpose of collecting native forage grasses and legumes. My primary interest was the collection of *Paspalum* species, especially different forms of dallisgrass, *P. dilatatum* Poir. Since common dallisgrass reproduces by apomixis and essentially no improvement has been made by conventional breeding methods, our objective was to find sexual forms of dallisgrass. Due to the increased cost of commercial fertilizers and the increased interest in forage legumes, Dr. Langford's major concern was the collection of native legumes.

We left the United States in early January 1975 and returned at the end of February. Material was collected in southern Brazil, Paraguay, and Uruguay. Initially we had planned to collect in northern Argentina; however, due to the unstable political situation in that country we were unable to collect. A maximum amount of plant diversity was anticipated in this region of South America because it is generally considered the center of origin of dallisgrass and other *Paspalum* species.

OBJECTIVES

The major objectives of the plant exploration trip were to: (a) locate and collect as many diverse forms of dallisgrass for the purpose of securing a highly cross-fertile, sexual type; (b) collect as many different *Paspalum* species as possible: (c) collect any other species of grasses which appear to have potential use; (d) collect as many different native legumes as possible.

In addition to the above objectives we received a number of requests for other species which are grown in that area of South America. We also collected nodules from some of the legumes obtained and soil samples from the root zone of grasses which were suspected of being associated with free living nitrogen fixing organisms.

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GENERAL PROCEDURES

Upon notification by the USDA that the trip was approved we contacted different people in each country for assistance in making arrangements or referral to someone who would be of assistance. Our itinerary was such that we first collected material in Rio Grande do Sul, the southern most state in Brazil. Then we went to Paraguay, Uruguay, and returned to Rio Grande do Sul.

Upon arrival in each country one or two days were spent with prearranged contacts concerning the best locations for exploration and collection, securing maps, interpreters and a vehicle, visiting herbaria, and arranging for the mailing of the plant material. In each country a person who was knowledgeable of the native grasses and legumes accompanied us. This person also served as a driver and interpreter. Although our means of transportation was normally by car or jeep, it did vary from horseback to private airplane. At each collection site the collection number, species collected, plant description, location, soil type, and any other pertinent information concerning the site or plant were recorded. Seed were dried, threshed, and packaged for mailing. The soil was washed from the roots of the vegetative material and then packed in sphagnum moss and placed in a plactic bag for mailing. All of the plant material collected was sent to the United States by diplomatic pouch and then forwarded to the U.S.D.A. Plant Inspection Station in Washington, D. C. for processing.

EXPLORATION AND COLLECTION

We flew to Porto Alegre, Brazil, the capitol of Rio Grande do Sul. Dr. Roger Hanson, who is with the University of Wisconsin U. S. AID program, was our contact and provided us with climatological and soil maps of the state. He also arranged a meeting with Dr. Ismar Barreto, an agronomist with the Universidade Federal de Rio Grande do Sul. Dr. Barreto is quite interested in Paspalum taxonomy and was very helpful in indicating the best areas to collect, location of different species, etc. He obtained a vehicle from the University for our travels and provided the services of Mr. Arnildo Pott, a taxonomist with interests in range management.

Porto Algre was used as a base of operation while collecting in that area. Then we went north to Vacaria and used it for a base of operation for several days. This was an area where we suspected considerable variability in dallisgrass. We started finding the yellow-anthered biotype of dallisgrass just north of the Rio das Antas. We found several different forms of dallisgrass in the Vacaria area. There were types which appeared to be intermediate between yellow-anthered dallisgrass and vaseygrass, P. urvillei Steud. It was in the Vacaria area where we first saw the converting of native pastures to cultivated crop land for soybeans and wheat. Undoubtly valuable germplasm was being lost because of this; however, we were soon to see that overgrazing by livestock probably resulted in even a greater loss of germplasm. We then explored and collected in the vicinities of Bom Jesus, São Francisco de Paula, and Torres. We returned to Porto Alegre and prepared the plant material for mailing.

We flew from Porto Alegre via São Paulo to Asuncion, Paraguay. Mr. Sanford White and Dr. George Ellis of the U. S. AID mission gave us much assistance. They provided an AID vehicle for our travels and also obtained permission from the Paraguayan Minister of Agriculture for two Paraguayan

agronomists to assist us on our trips. Before starting collecting, we reviewed the herbarium specimen at the National University and discussed the distribution of grasses and legumes with the Paraguayans.

Because of the distribution of roads in Paraguay we used Asuncion as our main base of operations. All of the grasslands around Asuncion and in the Southern part of the country were severely overgrazed. This was also true along the roadsides. The cattle density in this area was the highest encountered on the trip and severely affected our collection.

The Chaco region comprised the northwestern section of the country. It is all of the area west of the Uruguay River. The lower portion is a sub-tropical savanna; however, further to the northwest it becomes less tropical and is more of a desert shrub. P. alcalinum Mez is a species used in the Chaco. Buffelgrass, Cenchrus ciliaris L., was widely used in the upper Chaco and appeared to be the best adapted forage grass we encountered in this area.

There had been little rainfall in the Chaco and in the southwestern part of the country which affected our collections. The temperature was in excess of 100°F every day we were in Paraguay and was 115°F the days we were in the Chaco. Eastern Paraguay had more rainfall; however, since most of it was recently cleared jungle, there were limited pastures of any size.

We were fortunate in that Dr. Anibel Heisecke, a Paraguayan rancher, provided an airplane for us to fly to his ranches to search for grasses. Two of his sons had attended Texas A & M University and Dr. R. C. Potts, Associate Dean at Texas A & M, was responsible for this contact. This provided us an opportunity to explore in areas otherwise inaccessable. At one ranch there were no motorized vehicles so we traveled by horse. We flew to six ranches at different locations in the country.

The most common Paspalum species in Paraguay were P. notatum Flugge, P. plicatulum Michx., P. rojasii Hack., and P. guenoarum Arech. We saw very little dallisgrass which suggests that it is not native to this area of South America and very little has been introduced. Seed from 143 plants were collected and this included 89 Paspalum accessions.

Since we were unable to collect in Argentina, we flew from Asuncion to Montevideo, Uruguay. Our contacts were Dr. Bernardo Rosengurtt, an agrostologist with the Universidad de la Republica, and Mr. Juan Millot, an agronomist at an experiment station near Colonia. Upon arriving we underwent the normal orientation with them. They provided transportation for us and either one or both accompanied us during our travels. We used Montevideo, Colonia, Paysandú, and Tacaurembó as our bases of operation. We were able to cover most of the country. However, there was a severe drought in the upper two-thirds of the country. It was the worst in the areas of Melo, Tacuarembó and Rivera. This along with heavy grazing pressure severely limited our collections. In northern Uruguay we encountered temperatures in excess of 110°F. Due to the drought and overgrazing, we had the most success in areas inaccessable to cattle and sheep. These were small fenced areas and railroad right of ways.

A number of diverse forms of dallisgrass were found in Uruguay. The area of maximum diversity was near Minas in the south. It was interesting that the yellow-anthered forms of dallisgrass were found only in the southern third of the country. However, more different Paspalum species were found in the northern part of Uruguay. In spite of the deleterious conditions for collecting plant material, a total of 231 collections were made which included 111 Paspalums.

We flew from Montevideo to Porto Alegre, Brazil to complete the exploration of Rio Grande do Sul. After securing the services of Mr. Pott we rented

a vehicle and explored the southern half of the state. Rather than having a base of operations we traveled to Pelotas, Bagé, Dom Pedrito, Uruguaiana, Alagrete, São Gabriel, and Guaiba. We were able to collect several species that were unavailable in Uruguay because of the drought. Several forms of yellow-anthered dallisgrass were found near Bagé.

Prior to leaving Porto Alegre we made arrangements to visit with Dra. Johanna Dobereiner at the experiment station at Km 47 near Guanabara which is west of Rio de Janeiro. On our return flight to the United States we stopped in Rio de Janeiro and visited with Dra. Dobereiner concerning her work with nitrogen fixation in grasses. We were able to collect some additional Paspalum species at the station and in the Rio area. Seed of these plants were brought with us to Miami where they were forwarded to the USDA Plant Inspection Station in Washington D. C.

A total of 346 collections were made in Brazil and 216 of them were of Paspalums.

SUMMARY

The plant exploration and collection trip to Brazil, Paraguay and Uruguay lasted for two months. The cooperation and assistance we received from scientists in these countries and U. S. AID personnel was excellent. A total of 720 collections were made and these can be categorized as follows: 416 Paspalums which represents more than 50 species, 154 legumes comprising 27 genera; 117 grasses other than Paspalum species which represents 34 genera; and 33 miscellaneous collections. In addition to these approximately 30 soil samples were collected and 34 nodules samples were obtained from some of the legumes collected.

A number of diverse forms of dallisgrass were found and collected. Before the mode of reproduction and crossability of these plants can be determined they will have to be studied cytologically and evaluated in a hybridization program.

PRODUCING SEED OF TILLMAN WHITE CLOVER

By Pryce B. Gibson [1/]

Tillman was released in October, 1965, jointly by the Agricultural Research Service, U. S. Department of Agriculture and the South Carolina Agriculture Experiment Station.

In 1965 a few grams of breeder seed which is an equivalent of viable seed from each of three clonal crosses were produced in bee cages at Clemson. The few grams of breeder seed were sent to Oregon for use in a seed increase program. Reports on this venture were optomistic in 1966 and in early 1967. Later reports indicated that a series of unfortunate events resulted in near failure.

The Oregon program eventually yielded enough foundation seed to plant about 5 acres. In 1969 the 5 acres produced approximately one ton of registered seed. Part of the registered seed was made available to farmers in the Carolinas.

Late in 1967 because of the series of unfortunate events that occurred in Oregon, South Carolina applied for Tillman to be included in the National Foundation Seed Project. The application was approved in 1968 and a seed production program was promptly started. The N.F.S.P. soon produced adequate supplies of stock seed. Supplies of stock seed are now adequate and satisfactory reserves are in storage.

Production of certifed seed lagged. The FCX contracted with Cal/WEST to produce seed. Thus the FCX led the way in supplying seed to farmers. This year Sawan is marketing seed and supplies are reported to be adequate.

The N.F.S.P. demonstrated with Tillman as it has with cultivars of other species that it can quickly and with little risk of failure produce the stock seed of a new cultivar.

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ADVANCES IN RHIZOBIUM SPECIFICITY AND ITS SIGNIFICANCE TO FORAGE LEGUME BREEDING

By Joe C. Burton [1/]

Leguminous forage plants gather dinitrogen, (N_2) when nodulated by effective bacteria and need no N fertilizers. With fossil fuel dwindling and high prices of N fertilizer, interest in symbiotic nitrogen fixation has greatly expanded.

Symbiotic N_2 fixation is a complex interaction between three systems, the nodule bacteria, the legume host, and the environment. Maximum efficiency depends upon discreet matching of bacteria and plant for each particular environment. Certain workers (2, 5, 12) attach more significance to selecting the proper strains of rhizobia; others consider the plant as the most important symbiont (7, 8, 9). Maximum symbiotic N_2 fixation requires efficiency in both symbionts and will require the united effort of Agronomists and Microbiologists.

Rhizobium Strain Selection

The prime attribute in *Rhizobium* strain selection is effectiveness, the ability to work symbiotically with a particular host plant and provide sufficient N for maximum crop yield. N_2 fixing ability is determined by putting the bacteris and plant together under favorable conditions and measuring protein and yield. The new acetylene reduction technique for measuring nitrogenase activity should now make the screening process quicker and easier (1).

While N_2 fixing ability is essential *Rhizobium* strains equal in this property often differ in other qualities which are extremely important under field conditions. *Rhizobium* strains which are effective on a wide spectrum of host plants are much preferred over strains which are effective on only one or two hosts. Competitiveness or the ability to nodulate their host in the presence of numerous other infective strains in the rhizoshpere is a highly desirable quality (3, 11, 12). The ability of a *Rhizobium* strain to survive in soil in the absence of their host is very important particularly with reseeding annual legumes. Apparently some strains of rhizobia are better equipped than others to induce nodulation and fix N_2 in high N soils. Such strains are advantageous where leguminous crops are grown with grass or other non-leguminous crops which may require more N fertilizer.

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Rhizobium - *Trifolium* Reactions

The clovers are very important forage plants. All *Trifolium* species are nodulated by a single species of bacteria, *Rhizobium trifolii* and constitute a cross-inoculation group. This group is considered discreet because it contains only one plant genus. At one time, it was thought that strains of *Rhizobium* effective on one species such as red *T. pratense* L. or white *T. repens* L. clover would be effective on all clovers. The fallacy of this conclusion is illustrated in Figure 1.

Seven *Trifolium* species commonly grown in the U. S. were tested for N_2 fixing abilities in association with 8 strains of *Rhizobium trifolii* and two polyvalent or composite inocula "B" and "R". The parent host and origin of strains of *Rhizobium* are listed in Table 1. Only one of the *Rhizobium* strains was effective on as many as 4 species of clover. Two strains were effective on 3 species and one was effective on only two of the clovers. Three of the strains were not highly effective on any of the 7 test plants. Nodulation was abundant in all treatments.

The composite inocula were effective on a wider spectrum of host plants than the single strain cultures. Inocula "R" and "B" were effective on 6 and 5 respectively of the 7 *Trifolium* species.

Cultivars differ in N_2 fixing abilities with strains of Rhizobia

Three cultivars of *T. repens*: Ladino, New Zealand white and Louisiana S-1 were tested for N_2 fixing ability in association with 9 strains of rhizobia (Figure 2).

Two of the nine strains of *Rhizobium* were effective on all three cultivars of *T. repens*. The majority of the strains were effective on only one cultivar. Strain T-85 and T-86 were ineffective on all cultivars of white clover, but were effective on *T. fragiferum* L. cv. Salina.

The two cultivars of Strawberry Clover, Salina and Palestine varied widely in their response. Six of the 9 strains of Rhizobia were effective on Salina Clover but only one of these strains, PP1, was effective on Palestine. Several of the strains were moderately effective on Palestine Clover.

Two strains of Rhizobia which were effective on Ladino Clover, S5 and S7, were completely ineffective on Strawberry Clover, (Fiqure 2). A reverse relationship was noted with strains T-85 and T-86. These were effective on Salina Clover, but completely ineffective on the three cultivars of *T. repens*.

Seven of the nine strains of *R. trifolii* were either effective or moderately effective on Red Clover, *T. pratense*. Strains T-85 and T-86 were ineffective on both Red and White Clovers. Nodulation was abundant on all of the inoculated plants.

Rhizobia - Plant interactions with 15 uncommon Trifolium species.

Fifteen *Trifolium* species, from Turkey, Israel, Australia, Spain, and Morocco were tested for N_2 fixing ability with 6 strains or rhizobia obtained from diverse geographical areas and which were all effective on ther parent hosts, (Figure 3). The shortage of seeds and low germination prevented obtaining reaction with all bacteria-plant combinations.

Strain Y6, an isolate from *T. vesiculosum*, was effective on 14 of 14 *Trifolium* species. P17, an isolate from Red Clover, was effective on 7 of 13

TABLE 1.--Parent Hosts and Geographical Origin of Strains of Rhizobium trifolii referred to in this paper. Listings are alphabetical according to species name.

R. trifolii Strain	Parent Host	Geographical Source	Other Description
B4	*T. alexandrinum* L.	Unknown	Hollowell 10-2
C6	*T. ambiguum* M. Bieb.	Missouri, USA	-----
CC1	*T. burchellianum*	Rhodesia	Corby
G14-G16	*T. hirtum* All	California, USA	-----
K10	*T. incarnatum* L.	Mississippi, USA	-----
K12-K13	*T. incarnatum* L.	Alabama, USA	-----
P17	*T. pratense* L.	Wisconsin, USA	UW 203
P30	*T. pratense* L.	-----	Hansen 17
PP1	*T. purpureum*	California, USA	-----
T85-T86	*T. purpureum*	California, USA	-----
S5	*T. repens* L.	Florida, USA	-----
S7	*T. repens* L.	Kentucky, USA	-----
T2	*T. semipilosum*	Kenya	CB526
X11	*T. subterraneum* L.	Australia	Jensen 67-3
X13	*T. subterraneum*	Australia	WA67
X31	*T. subterraneum*	Australia	C2480a
X32	*T. subterraneum*	Australia	WU290
Z1	*T. subterraneum*	Australia	TA1
X7	*T. subterraneum*	USDA	Erdman 3DIW9
X15-X19	*T. subterraneum*	California, USA	-----
X33	*T. subterraneum*	California, USA	Munns #1
X34	*T. subterraneum*	California, USA	Munns #3
X16-X84	*T. subterraneum*	California, USA	-----
XX1	*T. usambarence*	Africa	Norris C6771
C6	*T. ambiguum*	Mississippi, USA	-----
Y1	*T. vesiculosum*	Wisconsin, USA	-----
Y10-Y17	*T. vesiculosum*	Alabama, USA	-----

clover species. Strain X31, a highly effective Rhizobium strain from subterraneum clover, was effective on 7 of 13 species. The isolate C6 from Kura Clover T. ambiguum was not effective on any of 13 Trifolium species included, and failed to produce nodules on 4 of these 13 species. Rhizobium Strain T2, and isolate from T. semipilosum, one of the African species of clover was very effective on T. compactum, but completely ineffective on the other 14 clover species. It produced nodules on all but 2 of the clovers. The African Clovers are noted for their high degree of specificity and lack of response to Rhizobium strains which are highly effective on clovers grown in the U. S. Finally, Strain XXI isolated from T. usambarense, also an African Clover, was effective only on T. occidentale. This strain failed to produce nodules on 8 of 11 of the clover species.

The diversity of reactions obtained here serves to demonstrate the complexity of Rhizobium - plant associations even in one of our most discreet cross-inoculation groups. It is clear that the only way to determine whether Rhizobium "A" will work effectively with Legume host "B" is to put them together under conditions suitable for symbiotic N_2 fixation and note the results.

Infectiveness vs Effectiveness in Nodule Bacteria

One of the desirable qualities in rhizobia mentioned earlier was "Competiveness" or the ability to nodulate their host grown in a soil which harbors large numbers of native or carry-over rhizobia capable of infecting it. The number of rhizobia which can be applied to seed is very small in relation to the numbers in soil following a crop of a leguminous plant of the same cross-inoculation group. When these carry-over rhizobia are ineffective on the legume to be planted, it demands the largest possible inoculum of effective rhizobia and they must have this quality called "Competitiveness" if the new crop is to thrive.

The indigenous flora of the Sierra Rangelands of California consists of a number of Trifolium species with little or no forage value (10). This native flora of Trifolium species has resulted in a native population of R. trifolii which is highly infective on Subterraneum and Rose Clover but produce ineffective or parasitic nodules. Successful establishment of Sub and Rose Clovers requires large inocula of highly competitive effective R. trifolii strains (12).

Selecting Rhizobium strains for "Competitiveness"

The most common method of measuring "Competitiveness" is to inoculate the seed with a test strain which can be distinguished from rhizobia in the rhizosphere either culturally or serologically. The nodules on the plants are sampled and tested to determine the relative numbers of nodules produced by the inoculum strains. The two most serious difficulties with this method are: 1) It is very time consuming and 2) the technique is limited to comparison of rhizobia with different serological patterns.

A Lenoard jar technique in which seed are inoculated with the effective strains and planted in sand containing an inoculum of ineffective rhizobia has worked well in selecting Rhizobium strains for Subterraneum and Rose Clover planted on the Sierra Rangelands of Northern California. New isolates of rhizobia are first tested for N_2 fixing ability. The most effective Rhizobium

strains are then tested for competitiveness using the Leonard jar technique. After a 6-week growth period plants are harvested, dried and analyzed for total N. Strains of rhizobia differ greatly in their ability to fix N_2 without competition from ineffective bacteria in the substrate. The majority of the strains fix larger amounts of N when planted in the sterile sand as compared to those planted in the sand containing the ineffective rhizobia (Figure 4). However, the most effective strains as measured in sterile sand are often not the most effective when they have to compete with the rhizosphere rhizobia. In pure culture, Strain X15 was more effective than Strains X16, X17, X18, and X19, but in the competition series, X15 was inferior to these same 4 strains (Figure 4).

Rhizobium strains which prove the most competitive in the growth chamber tests are further tested under field conditions. Peat-base inocula are prepared and tested under field conditions. In general, strains which demonstrate good "Competitiveness" in the growth chamber also prove most effective in the field. Typical data are shown in Table 2. Strains selected for competitiveness by the Leonard jar mathod, combined with good inoculation practices have proven very successful.

TABLE 2.--Effect of strains of Rhizobium trifolii on Growth of Woogenellup, Subterraneum, and Hykon Rose Clovers. (Data from Dr. M. Jones, Univ. of Cal Davis. 1975)

Strain of R. trifolii	Woogenellup Middle	Woogenellup Orchard	Hykon Middle	Hykon Orchard
	Millimeters/Longest Leaf			
None	18 a[1/]	16 a	17 a	17 a
G 14	38 efg	26 c	43 cde	32 e
G 15	39 fg	26 c	44 de	28 bcd
X31	35 def	26 c	42 cd	26 b
X47	40 g	27 cd	44 de	27 bc
X68	40 g	30 de	39 c	29 cde
X84	39 fg	31 e	44 cde	27 bc

1/ Values within a column followed by the same letter are not significantly different at the 0.05 level.

One of the desired characteristics of rhizobia mentioned earlier was ability to survive in the soil or what some workers refer to as "saprophytic competence". This quality is particularly important with Subterraneum Clover, an annual which makes its growth in the rainy spring season, produces seed and buries them in the soil where they remain dormant during the dry summer season. The seeds germinate when the fall rains come. If the effective rhizobia do not remain viable in the soil during the hot dry summer season, little forage will be produced the following year. While no direct method has been devised to measure this quality, generally effective strains isolated from plants or fields which have been producing good Subterraneum and Rose Clovers for several years have also demonstrated good "saprophytic competence" during the 5 years these studies have been pursued.

Rhizobium competitiveness with Crimson and Arrowleaf Clovers

A large population of infective non-nitrogen-fixing rhizobia in the soil can make it difficult to obtain effective nodulation of many of our leguminous crops. Eleven strains of Rhizobium were highly effective on Crimson Clover T. incarnatum when the inoculated seed were planted in sterile sand (Figure 5). However, when these same effectively inoculated seeds were planted in sand containing an inoculum of ineffective rhizobia mixed into the sand, N_2 fixation was reduced by more than 50% with 8 of the 11 Rhizobium strains. Strains K12, K13, and Y10 demonstrated good competitiveness. The others would be considered poor competitors. When these same 11 strains of R. trifolii were tested on Arrowleaf Clover, T. vesiculosum, the competitive effect was even more marked (Figure 6).

Strain K12 brought about fixation of around 9 mg per plant when the seeds were planted in sterile sand but in the presence of the ineffective inocula only 1 mg N per plant was fixed. Eight of the eleven strains were very poor competitors. Strains Y13, Y14, and Y17, recent isolates from field grown Arrowleaf Clover, showed a high degree of competitiveness. These are the strains that should be used under field conditions.

Soil rhizobia can influence legume crop rotation

The importance of selecting rhizobia which are effective on a wide spectrum of host plants was mentioned earlier. Several annual Trifolium species may be adapted to any particular geographical area. Crimson, Rose, or Subterraneum Clover mixtures might be grown in the Northwest or Southeast U.S.A. Strains of rhizobia effective on one of these clovers are often ineffective on another.

Strains X33, X34, X35, and X37 are effective on Subterraneum Clover but almost completely ineffective on Crimson and Rose Clovers, (Figure 7). Woogenellup Clover inoculated with any of these strains should grow well but it would not be wise to change to Rose or Crimson Clover the following year. On the other hand, strains X15, X19, and X31 are effective on Subterraneum, Crimson, and Rose Clovers. Use of wide spectrum strains such as these would permit growth of any one or a mixture of the 3 Trifolium species without any buildup of ineffective rhizobia in the soil. Considerations should be given to the rhizobia content of soils as well as levels of phosphorous, potassium and other nutrients.

This discussion has been concerned exclusively with Rhizobium Trifolium interactions. The phenomena reported here occur also with Lotus sp. (2) Medicago sp., Vicia faba, the Mung Bean Phaseolus radiata (4) and possibly many others. The microflora of ineffective rhizobia is a very determinate factor in successful inoculation of legumes with highly efficient strains.

The Host Plant as a Symbiont

So far attention has been given only to the good characteristics of the Microsymbiont. Certain workers (7, 8, 9) have suggested that the plant is the major factor controlling N_2 fixation because it is the plant which must capture the solar energy and make it available for the fixation process. There is good evidence to support this postulate in the case of grain legumes but the arguments are less convincing with the forage legumes which usually

have a longer growing season, and produce comparatively lower yields of small seeds, even when allowed to mature before cutting. Nonetheless, it can not be denied that the host plant is a very important factor in an effective N_2 fixing association and plant geneticists will need to pay heed to N_2 fixing genes carried by the host plant. Up to now the Rhizobiologist has little access to new plant development until they are ready for introduction to the public. It is then his task to find effective Rhizobium Strains for the new plant material.

It has generally been conceded that nitrogenase, the enzyme responsible for reduction of N_2 was a product of symbiosis and that neither symbiont alone could produce it. Recent findings (6, 13) negate this idea. It has been convincingly demonstrated that certain strains of cowpea rhizobia can produce nitrogenase in pure culture. Further, it has been demonstrated with $^{15}N_2$, that these pure cultures of rhizobia fix nitrogen. The importance of this can not be assessed until more data on amounts of N_2 fixed are available. Certainly it is still doubtful that the rhizobia alone can provide any substantial quantities of N fertilizer. We shall still have to use the leguminous host to capture the solar energy. The challenge here is to find what other factors the leguminous plant contributes in symbiotic N_2 fixation.

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Figure Legends

Figure 1. Reactions of 7 species of *Trifolium* to inoculation with 8 strains of *R. trifolii* and 2 multiple strain inocula "B" and "R". Reactions are arbitrarily classed as effective, moderately effective, or ineffective based on total N-content. When plants contained 75 to 100% as much N as the best inoculation treatments and plants were vigorous and colored deep green, the reactions were classed effective. When plants contained 50 to 75% N content of best treatment the reaction was designated moderately effective. Plants with less than 50% of the best total N content were classed ineffective.

Figure 2. Reactions of 3 cultivars of *T. repens*, 2 cultivars of *T. fragiferum* and 1 cultivar of *T. pratense* to inoculation with 9 different cultures of *R. trifolii*.

Figure 3. Response of 15 *Trifolium* species from Australia, Turkey, Spain, Morocco and Israel to 6 diverse strains of *R. trifolii*.

Figure 4. N_2 fixation by *T. subterraneum* cv. Woogenellup to 8 strains of *R. trifolii* isolated from surviving thrifty subterraneum clover plants from poor fields in Northern California. Inoculated seed were planted in sterile sand and in sand containing an inoculum of ineffective rhizobia from the same area.

Figure 5. N_2 fixation by *T. incarnatum* to inoculation with 11 different strains of *R. trifolii* in sterile sand and in sand containing an inoculum of ineffective rhizobia.

Figure 6. N_2 fixation by *T. vesiculosum* cv. Yuchi inoculated with 11 strains of *R. trifolii*. Effectively inoculated seeds were planted in sterile sand and in sand containing an inoculum of ineffective rhizobia.

Figure 7. N_2 fixation by *T. incarnatum*, *T. subterraneum* and *T. hirtum* to inoculation with 7 strains of *R. trifolii*.

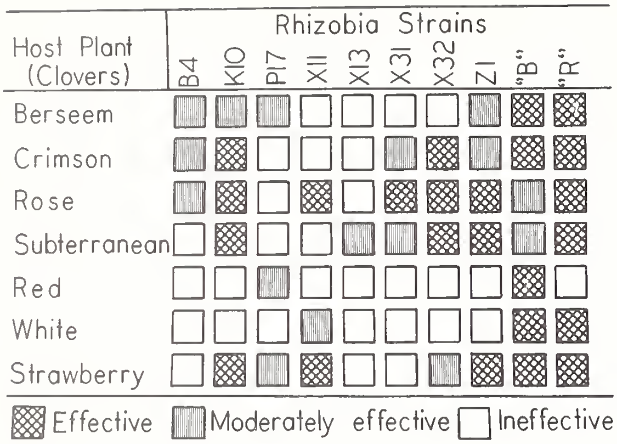

FIGURE 1

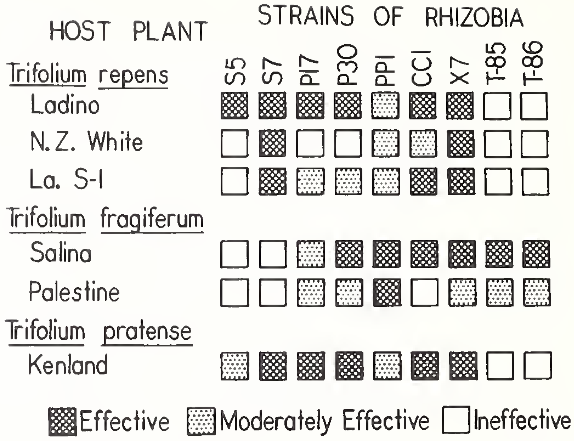

FIGURE 2

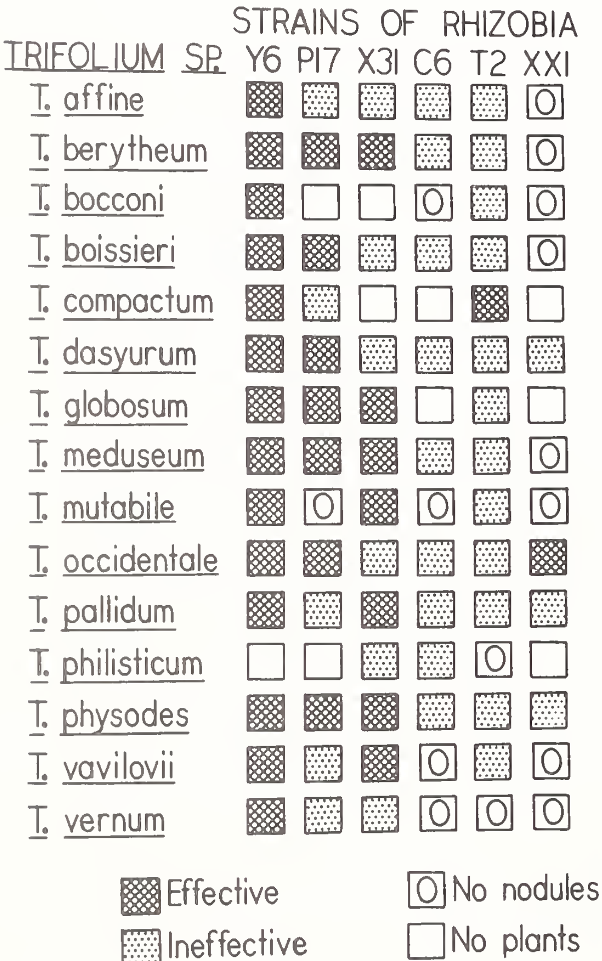

FIGURE 3

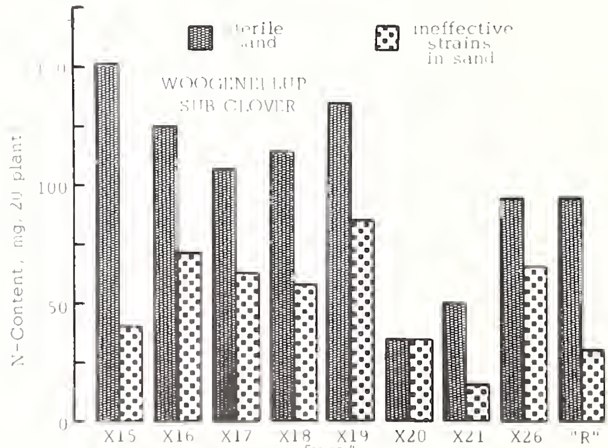

FIGURE 4

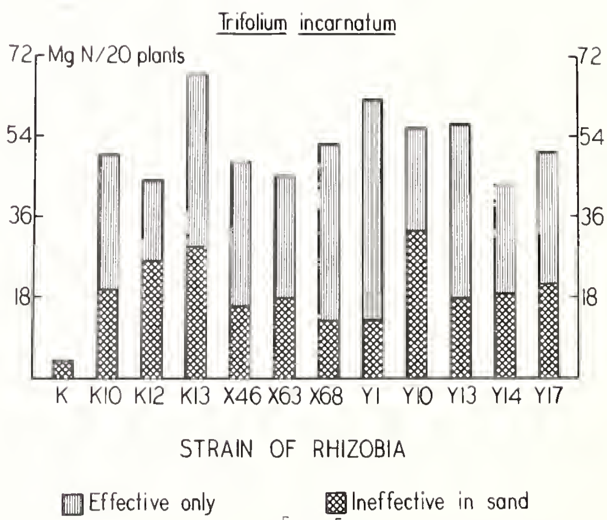

FIGURE 5

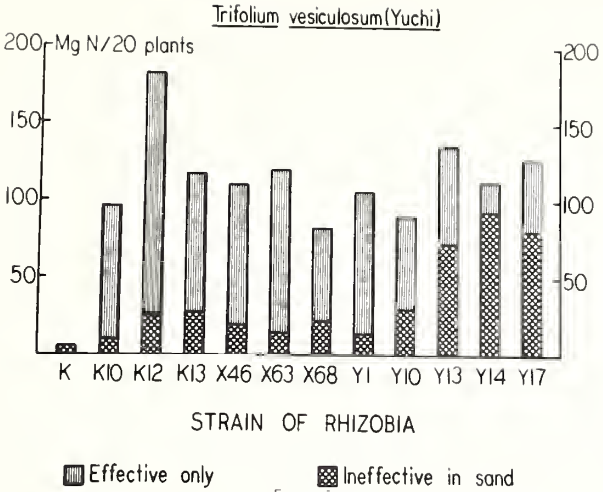

Figure 6

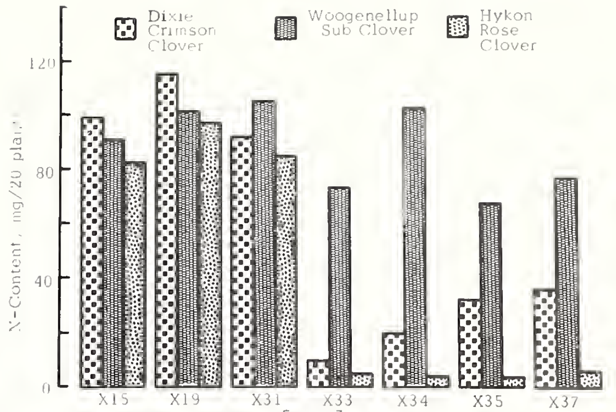

Figure 7

INOCULATION TECHNIQUES FOR TEMPERATE FORAGE LEGUMES AND THEIR AFFECT ON RHIZOBIUM SURVIVAL

By Richard W. Weaver [1/]

ABSTRACT

The purpose of this presentation is to aquaint the reader with some of the history of the inoculum industry as it pertains to development of better inoculation techniques. Discussion and data are largely limited to inoculation of forage legumes. However, the concepts on objectives of inoculation and the need for inoculation are valid for all legumes. Data is presented illustrating the importance of using an adhesive in attaching the inoculum to seed and in pelleting inoculated clover seed with lime when planting in acidic soils. Inoculum placement is evaluated because of the limited mobility of rhizobia in soil and the opportunity this offers in restricting nodulation to that portion of the soil environment that is most favorable for nitrogen fixation.

INTRODUCTION

Rhizobia capable of forming an effective symbiosis with clovers grown on soils of the Southern region are not normally present in adequate numbers for early, effective nodulation. They must be added to the soil when the legume is planted if effective nodulation is to occur. In Texas, Abon Persion clover, Louisiana S-1 white clover, Meechee arrowleaf clover, and subterranean clover must be inoculated with a commercial inoculum at planting to achieve effective nodulation (personal observations). Without the proper rhizobia to form abundant nodulation on the plant efficient dry matter production is not possible. The objective of inoculation is to provide adequate numbers of effective rhizobia to nodulate the legume and supply the nitrogen needed for efficient production.

The Australians suggest a minimal inoculum level of 300 per seed when the seed is sown under ideal conditions for survival of the rhizobia and no competitive rhizobia are present in the soil (16). When ineffective rhizobia are present or soil conditions are not favorable for survival of rhizobia several thousand effective rhizobia must be added per seed to insure effective nodulation (24, 27, 46, 47, 48). Unfortunately, many of the soils in the Southern region have ineffective rhizobia present and must be thoroughly inoculated using the best inoculation practices at planting if they are to efficiently produce clover (29, 45).

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Inoculum Carrier

The earliest method of inoculating legumes was accomplished by spreading soil from an area that grew well nodulated plants of the appropriate species to the field that was to be inoculated. Soil transfer as a method for inoculating legumes was successful when enough soil was transferred to supply adequate numbers of the needed rhizobia (18). Obviously, it was difficult to know how much soil to use because soils vary by at least five orders of magnitude in the numbers of rhizobia present (27). This means that a few pounds of one soil would be a suitable inoculum but several thousand pounds of another soil would be required. Normally several hundred to a few thousand pounds of soil were used to inoculate each acre of the field being planted (18). Besides difficulties in transferring soil there were the disadvantages of transferring weeds and plant disease organisms with the soil from field to field.

Shortly after rhizobia were isolated from nodules in 1888 by Beijerinck pure cultures of rhizobia were prepared commercially for use by farmers. The first cultures were produced in 1895 and consisted of organisms grown on a gelatin slant containing required nutrients. The farmer removed the rhizobia from the slant and applied them to his seed in a water suspension. This technique did not have the disadvantages of the soil transfer method but did not gain wide acceptance because results were inconsistent and sometimes the crop yields were less than that achieved by the soil transfer method (18).

A new pure culture technique of inoculating legumes was developed and marketed in 1902 (18). The rhizobia were cultured and distributed to the farmer in a liquid medium. Unfortunately, this method was also inferior to the soil transfer method in providing viable rhizobia to the germinating seedling. Commerical cultures continued to compete with soil transfer methods until the early 1940's (31).

In the late 1930's the present inoculum carrier, peat, was coming into use (30). It soon replaced the soil transfer method and by early 1940's was the principal inoculum carrier being used (31). Peat provided a suitable environment for relatively longterm survival of rhizobia (Figure 1) and was a suitable form of inoculum for unskilled workers to use. Presently, a peat base inoculum is the only one recommended in Australia and the principal one used in the U. S. (8, 43).

Even with the peat carrier, precautions against excessive heating (Figure 1) and drying of the inoculum must be made (7, 9). The latter is accomplished by adjusting the moisture content of the peat to the proper level and sealing the peat in a plastic bag that provides some aeration without moisture loss (9, 43). The moisture content of the peat is critical in survival of the rhizobia as is selection and modification of the peat before the inoculum is mixed with it (35, 36, 37, 39).

Long term storage of viable rhizobia has been accomplished by freeze drying techniques (34). The principal disadvantage of this technique was the high death rate of freeze dried rhizobia on seed (43). Seed inoculated with 10,000 rhizobia per seed from a freeze dried culture only had 30 viable rhizobia 1 day after inoculation and none after 7 days whereas seed inoculated with a peat inoculum had ten times more surviving at 1 day and 25 per seed at 7 days (15). Because of this poor survival on seed, freeze dried techniques have been used little in recent years.

Inoculum Adhesive

It was recognized early that rhizobia move only short distances in soil and must be placed in the vicinity of the plant root (18). The early inoculation method of soil transfer revealed this when it was shown that several hundred pounds of inoculum applied to the soil was no more effective than applying a fraction of a pound to the seed (18). The soil was applied to the seed as a slurry and upon drying would stick to the seed.

The use of an adhesive with inoculum not only provides for better distribution of the inoculum on the seeds but greatly increases the survival of the rhizobia (Figures 2 and 3). Many adhesives have successfully been used to increase the survival of rhizobia on seed (4, 14, 15, 16, 21, 44). They include, in increasing order of protection afforded the rhizobia, glucose, cellobiose, lactose, sucrose, raffinose, sorbitol, maltose, dextrine, hydroxypropyl cellulose, carboxymethyl cellulose, methyl cellulose, and gum arabic. One problem with using the better adhesives, has been their lack of availability at the retail store. With greater farmer awareness on the usefulness of this material it can be supplied with the inoculum by the inoculum manufactures. In fact at least one inoculum manufacturer has had an adhesive on the market for years (THE NITRAGIN COMPANY, Milwaukee, Wisc.). The only adhesives readily available from most local retail stores are sucrose and milk. A 25% water solution of sucrose used as an adhesive in inoculating alfalfa seed with a peat inoculum decreased the death rate of rhizobia by a factor of 800 after only 2 weeks storage at 24C (9). No data was available on the protection actually afforded by milk.

The adhesives extend the survival of rhizobia by reducing the harmful effects of desiccation (44) and protect the rhizobia from substances on seed coats that are toxic (2, 40, 44). Glass beads and seeds inoculated with a broth inoculum and stored at 24 C with and without adhesives illustrate the importance of the adhesive in extending the survival of the rhizobia (Figure 3).

Inoculum Pellet

When rhizobia are inoculated into soil their chemical and physical environment is drastically changed. One of the most important changes that may occur is pH. Rhizobia capable of nodulating most temperate forage legumes are very sensitive to a soil pH of 5.5 or below (42). In fact they may die before nodulating a host in soils of pH 5 or below (39, 42). To alleviate this problem a technique was developed to coat the legume seed with a neutralizing agent to increase the pH in the vicinity of the seed (32). The principal pelleting material used was fine particle $CaCO_3$. This agricultural lime must not be confused with hydrated lime or slak lime because these materials are very caustic and will kill the rhizobia and possibly the seed.

Pelleting clover seeds with lime is a popular practice in Australia (4, 6, 16, 36) and has been used in the U. S. with good results (24, 26, 29, 45). Pelleted seed planted into soil of pH 4.4 had more than 100 times as many viable rhizobia as nonpelleted seed (14).

Pelleting materials other than $CaCO_3$ have been used but were not found to be superior (4, 16, 23). A detailed description of the pelleting procedure using $CaCO_3$ has been provided in several publications (1, 26, 36, 43), but for the convenience of the reader a description is provided in Appendix A.

Soil Conditions

The physical, chemical, and microbiological condition of the soil have large effects on whether inoculation is successful or not. Two physical conditions that affect the survival of the rhizobia are moisture and temperature. The chemical conditions are soil pH, and the mineral makeup of the soil. Many actinomycetes, fungi and other microorganisms are present in the soil that are antagonistic to the rhizobia. A short discussion on each of the topics on soil conditions as related to survival of rhizobia follows. Soil pH will not be discussed because it was covered in the section on pelleting.

Soil moisture has both an indirect and a direct effect on the success of inoculation. If soil is dry at planting the seed may not germinate for several days or even weeks. With such conditions the rhizobia must survive in the soil for an extended period of time. Soil moisture content has a direct effect on the survival of the rhizobia (43). The population of clover rhizobia decreased 90% when exposed to 60% relative humidity for 1 day but did not decrease when humidity was maintained at 100%. This may not be as drastic as it might seem because the relative humidty in soil at the permanent wilting percentage of plants is near 100%. However, if the rhizobia are on seed sown at the surface of the soil, desiccation could have a strong effect on their survival.

Soil moisture content affects the movement of rhizobia. Rhizobia in soils that are at field capacity or drier do not move more than a few millimeters per day (20). Seedlings from seeds growing 3 cm. to the side of the inoculum may not be nodulated (10). The inoculum must be located next to the seed or where a plant root will grow into it (38).

High temperatures are very detrimental to rhizobia. In laboratory media rhizobia do not generally survive temperatures above 43C (3). Bare surface soil temperatures in Texas exceed 65 C (personal communication M. E. Bloodworth) during the warmest months but are usually less than 40 C at 5 cm soil depth (19, 50). Fortunately the clay in soil increases the soil temperature at which rhizobia can survive (33, 49). Numbers of viable rhizobia decreased 10 fold in some soils after raising soil temperature from 30 C to 50 C for 5 hours but populations in other soils did not decrease (33). The investigators determined that the clays illite, montmorillonite, and haematite provided protection to the rhizobia but kaolinite did not. Three 5 hour exposures of 50 C in 3 days reduced the population of rhizobia from 100,000 per g of a sandy soil to less than 1 per g. Mixing montmorillonite into the soil increased the survival of the rhizobia and more than 1,000 per g were viable after the same treatment.

For any organism to survive in soil it must be able to establish itself a niche where it is competitive with other organisms for energy material (17) and has a faster growth rate than the rate at which it is parasitized or poisoned by other organisms. In sterile soil rhizobia survived in high numbers but in nonsterile soils their numbers declined (10). Soil contains viruses, bdellovibrios, and protozoans that actively prey on bacteria. However, rhizobia would not likely be eliminated from soil by these parasites alone (12, 28). Numerous fungi and actinomycetes that were isolated from soil produced antibioties that stronly inhibited the growth of rhizobia in laboratory culture (10, 11, 41) and have been implicated in nodulation failures in the field (22, 25). The real significance of antibiotic producing organisms in limiting populations of rhizobia in soil has not been established although water extracts of soils contained substances toxic to rhizobia (25).

Soil moisture and temperature conditions that are optimum for early germination and emergence of clovers are satisfactory for survival of rhizobia. Seedlings from seed planted into dry soil or sown onto the surface of dry soil may not be promptly nodulated because the number of viable rhizobia surviving on or near the seed may be very low (21). The surface of bare soil in the Southern region is hot enough to suspect rapid death of rhizobia on exposed seed. Sod seeding or incorporating the seed into the soil could reduce the temperture in the immediate environment of the rhizobia by 10 C or more.

Because both soil temperature and soil moisture effect the survival of rhizobia and the rate of nitrogen fixation inoculum placement may be a way of maximizing nitrogen fixation and plant growth. Inoculum placed beneath the seed would form nodules on roots near the location of inoculum placement (38). Roots formed above the inoculum would not nodulate (13). Soil temperature and soil moisture will be different at various soil depths. Placement of inoculum in zones most favorable for nitrogen fixation would insure that soil environmental conditions would be the best that the particular soil could provide. Inoculum applied separately from the seed but precisely in the root region would provide for a way of planting concurrently with inoculation which should increase the viable rhizobia population in the soil.

CONCLUDING REMARKS

There has been much information published on inoculation techniques and their effect on nodulation and survival of rhizobia on seed and in soil. This information is important for an efficient legume program. We must use effective inoculation techniques if forage legumes are to succeed in our region.

The data discussed in this presentation has shown that inoculation of seed should if possible be performed at the time of planting. Under good storage conditions of 21 C and using the best inoculation procedures viable rhizobia on seed stored for 1 week would likely decrease by 50% to 99%. When inoculating seed an adhesive should be used, it increases the survival of rhizobia on the seed, extends their survival in the soil and aids in obtaining uniform distribution of inoculum. Inoculating one seed with a double rate of inoculant and not inoculating another is not very effective because rhizobia do not actively move in soil and only one seedling would be promptly nodulated. Gum arabic is the best adhesive that has been tested on extending the survival of rhizobia on seed but when it or a commerical adhesive is not available a 25% solution of sucrose is a fairly good adhesive and provides some protection to the rhizobia.

Seed pelleting with $CaCO_3$ is a good practice especially when the seed is sown in acidic soils. When seeding into acid soils pelleting is needed to allow enough rhizobia to survive to promptly nodulate the plant.

There is still much to be gained from continued efforts on development of better inoculation methods. Farmers would much perfer effective preinoculation of seed so that they need not be concerned about wetting seed and applying the inoculum when they are preparing for planting. Perhaps the development of granular forms of inoculum that are being marketed for soybean and peanut inoculation have a potential for use on temperate legumes. Such an inoculum would provide a way of inoculating clover or alfalfa the second year after planting and would provide inoculum pockets in the soil that could nodulate the stoloniferous roots of clover as they developed during the growing season. It is

not enough to merely develop an inoculation technique that provides for viable rhizobia (5) but the rhizobia must be located such that they come into contact with the root system.

Appendix A - Pelleting legume seed

Adhesive - Completely dissolve 100 gm of gum arabic, that does not contain a preservative, in 230 ml water. The gum arabic should be light in color and not acidic.

Inoculum - A high quality peat inoculum should be used at the rate of 70 g per 7 Kg of small seed (white clover) or 14 Kg of medium seed (subterranean clover).

Pellet - The pellet is formed by coating the seed with finely ground $CaCO_3$. It should pass a 30 mesh sieve. Pelleting with ordinary agricultural lime may not be successful because of its larger particle size. Plasterer's whiting is a good source of fine textured lime. Do not use slak lime because it is $Ca(OH)_2$ and would kill the rhizobia.

Procedure - Mix the dissolved gum arabic with the inoculum and pour the slurry onto the seed. Mix the seed to obtain thorough distribution of the inoculum. Add all at once 3.4 Kg $CaCO_3$ and mix rapidly until all seeds are evenly coated. This should require 1 or 2 minutes. Too short a time will leave free lime and poorly coated seed but too much mixing may result in cracking and flaking of the pellet on drying. Let the seed dry for a few hours in a cool location before planting.

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Figure Legends

Figure 1. The survival of Rhizobium meliloti in peat stored at different temperatures in moisture proof containers. (J. C. Burton, Unpublished Data).

Figure 2. The survival of Rhizobium trifolii on subterranean clover seeds inoculated with a peat inoculum slurry containing gum arabic, methyl cellulose or only water (15).

Figure 3. The survival of Rhizobium trifolii on subterranean clover seeds and glass beads inoculated with a broth inoculum containing gum arabic, maltose, or only water (44).

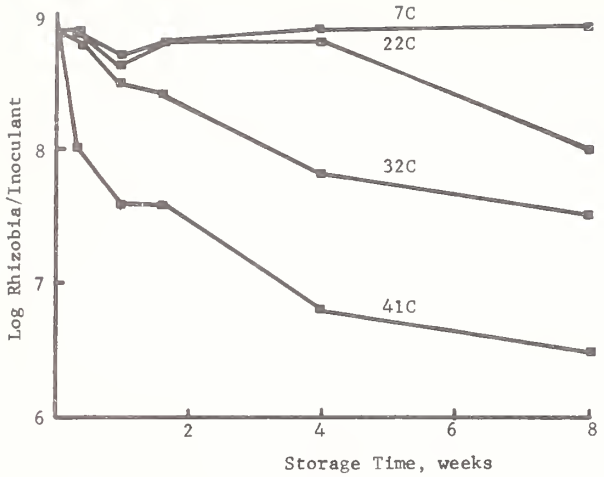

Figure 1

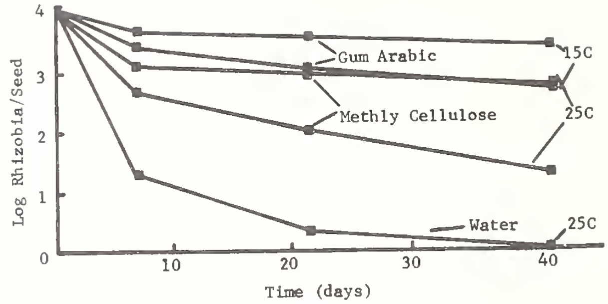

Figure 2

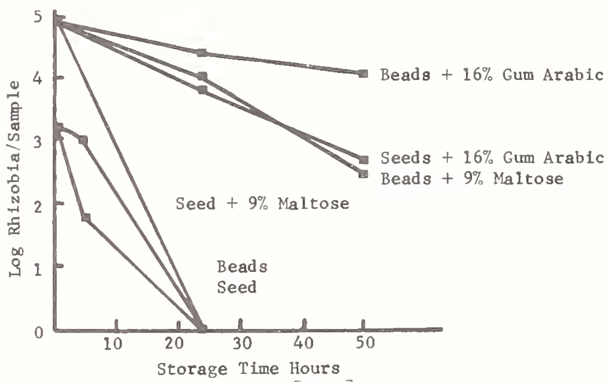

Figure 3

DIGITARIA GENOTYPES EVALUATED IN BRAZIL FOR NITROGENASE ACTIVITY, YIELD AND IVOMD

By Stanley C. Schank [1/]

ABSTRACT

Twenty-six digitgrass breeding lines were compared with four commercial cultivars of digitgrass and bermudagrass to determine possible dinitrogen fixation, nitrogen content, *In Vitro* organic matter digestibility (IVOMD), and yield. Commerical lines tested were 'Pangola', 'Transvala' and 'Slenderstem' digitgrass, and 'Coastcross-1' bermudagrass. Harvests were made every 28 days during 1974 at Km47, EMBRAPA, near Rio de Janeiro. During the year, accumulative dry matter (oven-dryed) of the lowest yielding line was 16,711 kg/ha/yr and the highest line yielded over 30,000 kg/ha/yr. Commercially available cultivars were intermediate in production, and not significantly different from each other at the 0.05 level. Seven of the breeding lines of digitgrass had yields surpassing Transvala. IVOMD data revealed that Transvala, and Slenderstem were significantly higher in digestibility than Coastcross-1. Pangola, with 61.9% IVOMD was not significantly different from Coastcross-1 (60.6% IVOMD). Four of the genetic lines were statistically superior in IVOMD with over 67% digestibility. Nitrogenase activity by acetylene reduction, a measure of the dinitrogen fixed on roots was monitered, with rates of over 500 gN_2/ha/day possible under favorable conditions. Nitrogen content of soil and plant material harvested from each plot was also monitered during the year.

INTRODUCTION AND REVIEW OF RECENT LITERATURE

Biological nitrogen fixation has become one of the most exciting areas of agricultural research (11, 12, 13). Dobereiner and coworkers in Brazil (6, 7, 8, 9) have identified the capacity of organisms in the rhizosphere of tropical grasses to fix considerable quantities of N_2 under certain conditions. Although this was first called non-symbiotic nitrogen fixation (in grasses) to distinguish it from the well known symbiotic relationship in the legumes, the evidence is accumulating that it is indeed an associative symbiosis, and more recent reports (4, 5, 10, 15) have reflected the change in terminology, calling it a symbiotic relationship in grasses also. With recent evidence that another C_4 grass, corn, is also a fixer of nitrogen (3), additional impetus has been given to obtain data on methods to maximize the grass-bacterial association.

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Day et al (5) state that since some tropical grasses have the potential to fix large amounts of nitrogen, plant breeders working in the humid tropics may well be able to promote this characteristic. Bulow and Dobereiner (3) likewise feel that N_2-fixation in grasses may be increased by plant breeding, citing significant differences in fixation between Paspalum notatum and Pennisetum purpureum cultivars. They also reported the mean nitrogenase activity of the best S_1 line of corn corresponds to a daily fixation of 2.4 kg N_2/ha/day, whereas the nitrogenase activity in the original cultivar only attained 0.1 kg/ha/day. The potential nitrogenase activity in maize roots approaches that of soybeans (3). Strains of Spirillum isolated Digitaria and corn also have recently been studied and compared (14).

Material and Methods

Twenty-six digitgrass breeding lines were introduced into Brazil, along with four commercial cultivars of digitgrass and bermudagrass, in January 1973. I increased these introductions and established a replicated trial at the Km 47 location in Brazil during the Spring of 1973 (October). After establishment, harvests were made every 28 days during 1974, for a total of 13 harvests. Dry matter yields were calculated on a gram per square meter per day basis, and ground samples were mailed to the Forage Evaluation Laboratory, Agronomy Department, University of Florida for analysis of In Vitro organic matter digestibility, and for nitrogen content using the Technicon auto analyzer. Soil analyses for nitrogen and other elements were completed in Brazil.

Detailed methods used for nitrogenase determinations have been reported (1, 5). Basically, samples of roots were collected in the afternoon from field grown plants, and placed in 60 ml serum bottles. The roots were dug with a hoe, dipped immediately into distilled water to prevent drying, and then were cut from the crown of the plant and placed inside the bottle. The bottles were evacuated 3 times and the atmosphere replaced by 5% O_2 in N_2, and pre-incubated overnight at room temperature. C_2H_2 (10% by volume) was injected in the morning and C_2H_4 production was measured three hours later by gas chromatography (2).

RESULTS

Accumulative dry matter yields for all thirty genetic lines in the test are presented in tabular form, ranking the highest yielding line first (Table 1). Statistical analysis (Duncan's Multiple Range Test 0.05 level) showed that lines 6 and 21 were significantly better than Transvala, and all lines lower in yield than Transvala. Line # 4 and all lines above it in yield were significantly better than # 16, all lines above # 27 were significantly better in yield than # 10.

More than 400 samples were taken during the year for nitrogenase analysis from an adjacent Transvala plot, and these data are plotted in Fig. 1. Yield of the cultivar Transvala is given in Fig. 2, and rainfall data for the comparative 28 day periods is presented in Fig. 3. Yield comparisons between Pangola and Transvala are given for each of the 13 dates of cut in Fig. 4. IVOMD data comparisons during the entire year are also presented graphically for Pangola and Transvala in Fig. 5.

All thirty cultivars were sampled for nitrogenase activity in January 1974 (mid-summer), and in March 1974 (180 samples each date). These data are

TABLE 1.--Accumulative dry matter yields for thirty genetic lines of digitgrass and bermudagrass in Brazil. Note: Species identity is given in Table 2. 200 kg/ha of N in ammonium nitrate fertilizer added to plots during experiment.

Identity No.	Variety or Genetic Line	Dry matter production $g/m^2/day$	Dry matter production kg/ha/yr	Mean% N Content of Forage	Kg of N In Forage Harvested	N Content of Soil (%) 0-25 cm depth Nov. 1973	N Content of Soil (%) 0-25 cm depth May 1975	N lost in soil kg/ha
6	Hybrid X46-2	8.24	30,008	2.46	738	0.083	0.076	140
21	UF 525	8.22	29,904	2.60	778	0.083	0.064	380
7	X 97-2	7.84	28,616	2.68	767	0.083	0.078	100
29	IRI 415	7.46	27,174	2.35	639	-----	-----	---
18	X2	7.42	27,028	2.44	659	-----	-----	---
25	X159-4	7.30	26,558	2.46	653	0.076	0.071	100
2	'Transvala'	7.29	26,550	2.40	637	0.098	0.045	1060
5	*Digitaria* sp.	7.18	26,135	2.56	669	-----	-----	----
28	X125-1	7.17	26,093	2.68	699	-----	-----	----
30	'Coastcross-1'	6.99	25,430	2.42	615	0.081	0.059	440
8	X143-29	6.92	25,258	2.49	629	-----	-----	---
14	X821-10	6.87	25,035	2.72	681	-----	-----	---
12	X750-2	6.83	24,861	2.67	664	0.090	0.078	440
24	X50-2	6.80	24,769	2.57	637	-----	-----	---
22	UF556	6.80	24,738	2.28	564	0.083	0.059	480
23	UF547	6.78	24,682	2.19	541	0.088	0.067	420
17	A-24	6.62	24,097	2.31	557	-----	-----	---
20	UF720	6.51	23,554	2.20	518	-----	-----	---
3	'Slenderstem'	6.47	23,433	2.34	548	0.071	0.064	140
1	'Pangola'	6.36	23,214	2.20	511	0.086	0.076	200
4	FL 299	6.30	22,932	2.57	589	-----	-----	---
13	X766-5	6.24	22,744	2.72	619	0.083	0.074	180
11	X729-9	6.14	22,411	2.60	583	-----	-----	---
27	1969 Selection	5.82	21,196	2.40	509	-----	-----	---
26	X124-4	5.75	20,913	2.63	550	-----	-----	---
9	X539-50	5.66	20,659	2.46	508	0.078	0.064	280
15	X844-2	5.49	19,970	2.81	561	0.090	0.062	560
19	X14	5.47	19,911	2.44	486	-----	-----	---
16	X863-4	5.00	18,197	2.72	495	-----	-----	---
10	X546-8	4.59	16,711	2.76	461	0.083	0.069	280

presented as Table 2, along with subsequent readings for nitrogenase samples made from core samples as described already (1). Although trends can be noticed in high and low fixing Digitarias, the variations within replications was so great that statistical analysis of the data was not attempted. However, it appears that genetic differences exist between lines of digitgrass in nitrogenase activity, and a more detailed study should be accomplished using these lines and others.

TABLE 2.--Nitrogenase activity in thirty cultivars of digitgrass and bermudagrass grown in Brazil. Both root samples and core samples were used. Data is expressed in n moles C_2H_4/g/root/hr.

Identity No.	Species designation	Root Samples Jan. '74	Root Samples Mar. '74	Core Sample
1.	Digitaria decumbens cv. 'Pangola'	6	13	880.6
2.	Digitaria decumbens cv. 'Transvala'	59	14	485.5
3.	Digitaria sp. cv. 'Slenderstem'	34	57	975.0
4.	Digitaria milanjiana Fl 299	12	27	-----
5.	Digitaria sp. unknown origin	21	9	425.6
6.	D. umfolozi x D. umfolozi	0	60	237.7
7.	D. umfolozi x D. milanjiana	1	8	264.9
8.	D. pentzii x D. pentzii	17	18	279.2
9.	D. umfolozi x D. milanjiana	1	6	-----
10.	D. valida x D. milanjiana	8	3	-----
11.	D. pentzii x D. milanjiana	7	3	-----
12.	D. milanjiana x D. milanjiana	0	1	194.2
13.	D. milanjiana x D. pentzii	0	0	-----
14.	D. milanjiana x D. valida	9	23	-----
15.	Hybrid 125-1 x D. umfolozi	0	4	-----
16.	D. valida x D. milanjiana	9	0	-----
17.	Digitaria pentzii A-24	1	16	-----
18.	D. pentzii x D. milanjiana	4	7	475.4
19.	D. milanjiana x D. milanjiana	10	1	-----
20.	Digitaria pentzii FL-720	20	15	292.3
21.	Digitaria umfolozi FL-525	0	22	268.0
22.	Digitaria swazilandensis FL-556	16	32	412.7
23.	Digitaria decumbens FL-547	14	26	-----
24.	D. milanjiana x D. valida	0	34	-----
25.	D. milanjiana x D. pentzii	14	11	445.0
26.	D. milanjiana x D. milanjiana	0	72	-----
27.	Digitaria 1969 Selection	4	15	254.9
28.	D. milanjiana x D. milanjiana	0	4	287.2
29.	D. milanjiana	0	7	89.2
30.	Cynodon dactylon cv. Coastcross-1	32	57	-----

* 3 core samples were taken from selected plots Oct. 28, 1974. Phosphate and molybdate fertilizer added to the cores and sampling for nitrogenase on November 14, 1974.

While in Brazil, I also made many root sections of Transvala using a freezing microtome or cryostat. The cortical cells of Transvala roots were often filled with bacteria. The photomicrographs taken were presented in the International Nitrogen Fixation Symposium (10). Although positive identification of Spirillum lipoferum within these cells must still be done using the flourescent antibody technique or by electron microscopy, the evidence continues to accumulate that they are indeed in the root rather than in the rhizosphere (15, 16).

ACKNOWLEDGEMENTS

Thanks are due to the staff of both soils and agrostology departments of IPEACS in Brazil for their cooperation in making the experiments possible. In Brazil, special thanks to Dr. Johanna Dobereiner, Dr. John Day, EnesioDelgado de Lucas, Gladstone Abrantes, Rui Melo de Carvalho, Paulo Roberto de Souza Faria, Ricardo Motta Miranda and Jose Bonifacio Meneses who aided in laboratory or field analysis. At Florida, tremendous back-up help was given by Dr. Rex L. Smith, Dr. G. O. Mott, Jan Ferguson, Dave Block, and Charity O'Neil. Dr. John Cornell and staff in the Statistics department of IFAS completed all the statistical analysis.

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Figure Legends

Figure 1. Nitrogenase activity on 'Transvala' digitgrass in Brazil during 1974. Each point on the graph is the mean of dozens of determinations summarized to coincide exactly with harvesting dates.

Figure 2. Yield data on 'Transvala' digitgrass in Brazil expressed in grams per square meter per day. Harvest dates were every 28 days during 1974.

Figure 3. Rainfall data at KM 47 in Brazil during 1974. Data is summarized to show the amount of rainfall in millimeters which fell in each 28 day period preceding the harvest.

Figure 4. Comparative seasonal yields of 'Transvala' and 'Pangola' digitgrass during 1974 in Brazil.

Figure 5. In Vitro organic matter digestibility (IVOMD) of 'Transvala' and 'Pangola' during 1974 in Brazil. Note the marked decrease in IVOMD during the dry winter period, late July, August, and September.

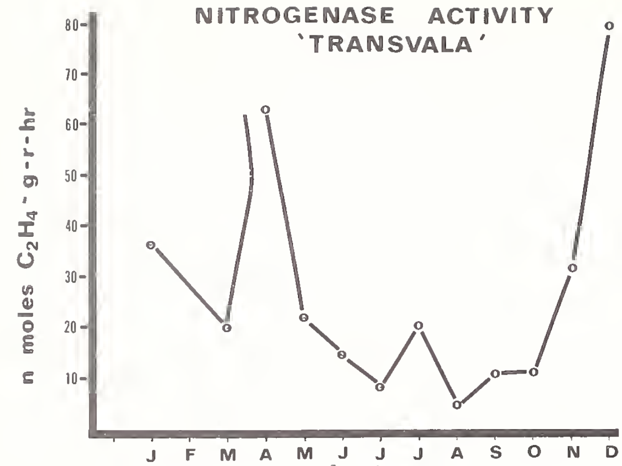

FIGURE 1

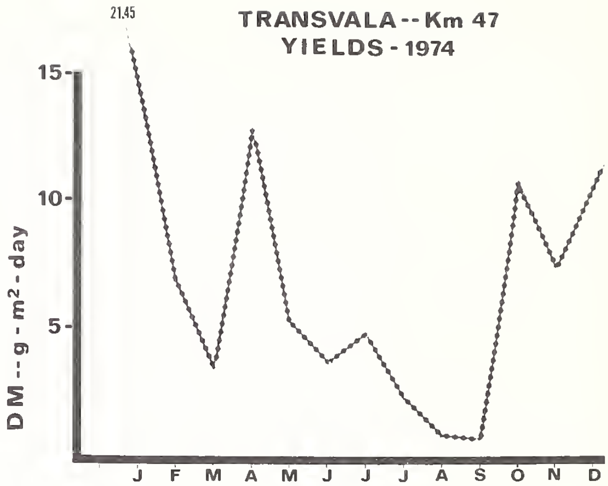

FIGURE 2

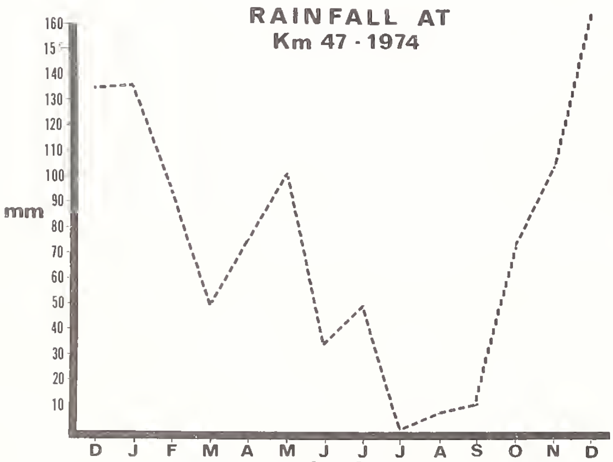

FIGURE 3

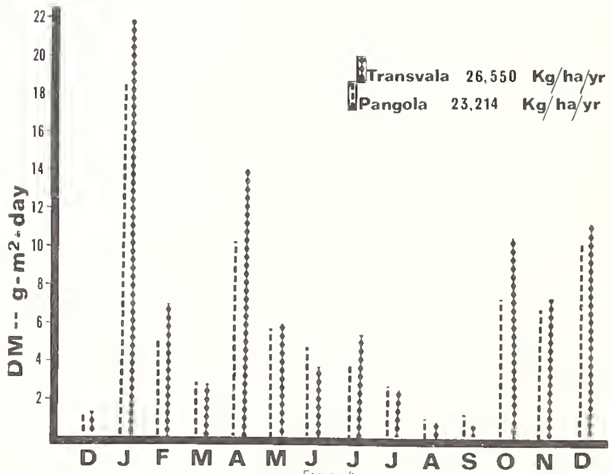

FIGURE 4

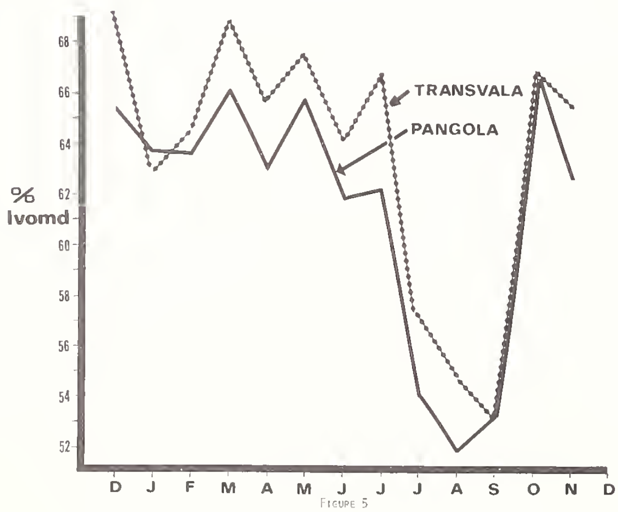

FIGURE 5

GRASS-BACTERIA NITROGEN FIXATION IN FLORIDA - PRELIMINARY RESULTS

By Rex L. Smith, M. H. Gaskins, S. C. Schank, and D. H. Hubbell [1/]

The energy crisis and the dramatic increase of nitrogen fertilizer prices has stimulated renewed interest in biological nitrogen fixation. Of special interest to us was the Brazilian work on nitrogen fixation by bacteria in association with grass roots. As grasslands are vast, the potential of these systems is tremendous and could make a very significant contribution toward nitrogen for large acreages.

Observations in Brazil on sugarcane and other grasses suggested that nitrogen was being biologically fixed because yields were higher than expected from unfertilized crops grown consecutively for many years. Nitrogen fixing bacteria (*Azotobacter paspali*) were found in large numbers on grass root surfaces of *Paspalum notatum* variety 'Batatais' (1). Later is was pointed out that most of the nitrogenase activity was associated with washed roots and not the rhizosphere soil. 'Balatais' was found to fix up to 90 lbs. of nitrogen/acre/year (2), whereas, other varieties of *Paspalum notatum* fixed little nitrogen. Conclusions were drawn that the bacteria-grass associations were genotype specific and that efficient fixation depended upon specific matching of the grass and bacteria (3). *Azotobacter paspali* was found to be widespread and was found in Florida as well as Brazil (3).

Work on sugarcane showed an association with the bacterium *Beijerinckia indica* which was abundent on the sugarcane roots. This bacterium was also active on roots of several other tropical grasses (4).

Further work revealed nitrogenase activity with *Digitaria decumbens* roots, in this case, the bacterium *Spirillum lipoferum* was responsible (5). Activity varied with genotype; 'Transvala' was 10 times more active in fixing nitrogen than 'Pangola'. Preliminary cytological observations of roots by Dr. S. C. Schank (5) revealed that the organisms were located inside root cells providing a symbiotic system which is considered necessary for efficient nitrogen fixation.

Convinced that the great potential warranted intensive research in order to utilize these systems, we initiated research and established a team approach. Our overall, long term objective is to produce efficient commercial systems that will reduce nitrogen fertilizer requirements and increase world food production. Our first work, reported here, was to screen grass genotype for ability to associate with *S. lipoferum* and fix nitrogen and to establish grass-bacteria associations, by means of inocultion, that would fix nitrogen.

In 1974, we screened 40 genotypes of tropical and subtropical grasses for response to inoculation with *Spirillum lipoferum* obtained from Drs. Johanna

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1/ Associate Professor of Agronomy; Plant Physiologist, ARS, USDA; Professor of Agronomy and Associate Professor of Soils, respectively.

Dobereiner and J. M. Day in Brazil. The grass genotypes belonged to five species, Digitaria decumbens, Panicum maximum, Paspalum notatum, Cenchrus ciliaris and Cynodon dactylon.

Two replications of paired plant plots were used. One plant of each pair was inoculated, the other served as a control. Inoculation was accomplished by applying 100 ml. of diluted (5 to 1) semisolid culture, liquified by a slow speed blender, to each plant crown and watering it in immediately. Control plants received medium without the bacterium in the same manner and amount as the inoculated plants. Inoculation was done two times, the first on July 31st and the second two weeks later. The first inoculum had sparse growth but second was seeded heavily and produced a good culture.

The inoculum culture medium was nitrogen free, contained malate (.5%) as the energy source and contained the usual inorganic minerals. The entire nursery received fertilizer at the rate of 0-40-80 with trace minerals added at establishment time. No nitrogen was applied and the soil was well depleted of residual nitrogen.

The forage was harvested October 4th and dry matter yields taken. Two varieties gave significantly higher yields when inoculated, 'Transvala' and Pm 285 (Panicum maximum); inoculated PM 285 also contained more protein. Dry matter yields and protein content are given in Tables 1 and 2.

TABLE 1.--Yield Response to Spirillum Lipoferum

Variety	Rep I	Rep II	Mean	% of inoc. Control
	G. Dry Wt.			
Transvala				
Inoc.----------------------------	367	223	300	163%
Not. Inoc.-----------------------	196	173	184	
PM 285				
Inoc.----------------------------	1,118	1,339	1,228	153%
Not. Inoc.-----------------------	850	749	800	

TABLE 2.--Crude Protein - percent of dry wt.

Variety	Rep I	Rep II	Mean
Transvala			
Inoc.----------------------------------	7.1	5.8	6.4
Not. Inoc.-----------------------------	6.6	6.6	6.6
PM 285			
Inoc.----------------------------------	11.3	9.1	10.2
Not. Inoc.-----------------------------	9.2	8.1	8.6

Acetylene reduction measurements were inadvertently delayed until after cool nights began. The plants that appeared to respond to the inoculation were moved into the greenhouse to avoid cold damage. Even with light supplementation the plants did poorly so acetylene reduction was delayed further until January. Only two genotypes, both Cenchrus ciliaris, gave favorable results (see Table 3). Here non-inoculated plants appeared to also be infected indicating that the organism had moved from inoculated to uninoculated plants, a distance of six feet. Lack of ethylene production in PM 285 and low activity in Transvala was attributed to poor condition and growth of the plants and their inability to supply photosynthate to the roots.

TABLE 3.--Acetylene Reduction of Grasses in the Greenhouse

Variety	Spirillum Inoculation -	Spirillum Inoculation +
	n moles/g/h	
Transvala	1.2	15.3
Coast Cross	.2	3.1
PM 285	1.2	1.4
B 68-12	248.7	45.6
B 1-2	82.9	115.8

This work gave good indications that we established grass-bacteria associations capable of improving yield by inoculation with Spirillum lipoferum and gave responsive varieties for future work.

We have been collecting "nitrogen fixing" bacteria from grass roots from Florida and Latin America. We found that enrichment could be facilitated by first surface sterilizing roots for up to 1 minute in 10% chlorox then plating the roots on nitrogen free medium. This process favors bacteria located inside roots which are of most interest.

Recently (Spring 1975) we inoculated field plots several acres in scope. Inoculum was produced in a bacteria fermentor 13 l per batch (courtesy of Dr. M. E. Tyler and James Millum, Bacteriology Department). Nitrogen free medium (0.5% malate) was used with 95:5 ($N_2:O_2$) bubbled through the liquid medium at 35^oC. A batch could be produced in 24 hours containing over 200 million organisms per ml.

Replicated experiments of those genotypes that appeared to respond in 1974 have been inoculated. Data from these experiments should verify that these bacteria-grass systems can be established artifically by inoculation. This is necessary for us to utilize these systems.

We are also screening over 1,000 genotypes of grasses in 12 different species in order to discover more efficient systems and materials for basic studies.

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GROWING CALVES TO YEARLINGS ON WINTER ANNUAL SMALL GRAINS AND GRASSES PLUS LEGUMES AND SUMMER PERENNIAL GRASSES 1/

By Sidney C. Bell 2/

The use of cool season annual small grains, grasses and legumes was evaluated during 1960 to 1970 at three locations of the Auburn University Agricultural Experiment Station (Tennessee Valley Substation, Belle Mina; Lower Coastal Plain Substation, Camden; and Gulf Coast Substation, Fairhope).

Animal gain from grazing yearling beef steers average 416, 390 and 314 pounds per acre for the Tennessee Valley, Lower Coastal Plain and Gulf Substations, respectively. The lower gain per acre at Gulf Coast was attributed to use of this land for double cropping with soybeans. There was a higher stocking rate at Tennessee Valley, 1.90 compared to 1.32 at Lower Coastal Plain and 1.19 at Gulf Coast Substation; but the average daily gain was lower at Tennessee Valley, 1.49 pounds compared to 1.58 at Lower Coastal and 1.70 at Gulf Coast Substation.

A four-year study, recently completed at the Black-Belt Substation, 1969-1973, used grazing on wheat and ryegrass grown in rotation with corn silage and soybeans. Pasture was grazed 187.5 days with an average of 1.21 head per acre. Average daily gain was 1.91 pounds per day. Total gain per steer was 358 pounds with a gain per acre of 433 pounds.

Steers were purchased at $38.05 per cwt. and sold for $36.23 per cwt. and had a feed and pasture cost of $13.73 per cwt. of gain. This resulted in a return above feed and pasture cost of $61.66 per steer or $74.61 per acre.

Budgets were developed from research data using current prices for inputs and $30.00 per cwt. for stockers (buying and selling price) for three systems, rye, rye-grass and rye-ryegrass-clover. The addition of ryegrass or ryegrass and clover gave about 25-30 more days of grazing and the pasture with clover gave the highest net return to operator's labor and management, $24.48 per acre compared to $14.08 for rye-ryegrass and $3.42 for rye alone.

Summer Perennial Grasses

Another study at the Black-Belt Substation compared gain and returns on Dallisgrass alone, with Dallisgrass and clover mixture and also half Dallisgrass and half clover. Costs per hundred pounds of gain with today's prices, indicated a big advantage for the treatments with clover. The costs per

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1/ Paper presented at 32nd Annual Pasture and Forage Crop Improvement Conference, Texas A & M Agricultural Research and Extension Center at Overton, Longview, Texas, May 1975.

2/ Professor of Agricultural Economics, Dept. of Agriculture Economics and Rural Sociology, School of Agriculture and Agricultural Experiment Station, Auburn University, Auburn, Alabama.

hundredweight of gain were $23.52 for Dallisgrass alone, $16.55 for mixture and $17.62 for half Dallisgrass and half clover.

Bahia and Coastal bermuda, at various rates of nitrogen, were compared in a six-year study at the Wiregrass Substation. Coastal had higher stocking rates than bahia and also had higher gain per acre for each level of nitrogen. Gain per acre varied from 259 pounds up to 369 for bahia and from 308 pounds up to 675 for Coastal.

At current prices of inputs, including $180 per ton for ammonium nitrate, and $30.00 per cwt. for stockers, it did not pay to use nitrogen on bahia nor Coastal bermuda. Using $40.00 per cwt. for stockers, the most profitable level of nitrogen was 80 pounds per acre for bahia and 320 pounds for Coastal.

Even at $50.00 per cwt. for stockers only 80 pounds of nitrogen was most profitable for bahia. Using $120 per ton for ammonium nitrate, the price of stockers had to be $50.00 per cwt. to justify use of 160 pounds of nitrogen on bahia for most profit. At this combination of prices, 320 pounds of nitrogen was most profitable for Coastal.

At comparable levels of nitrogen use and prices, Coastal paid from $10.00 to $15.00 per acre higher net returns than bahia.

RESEARCH IN TENNESSEE RELATED TO GRASS TETANY

By John H. Reynolds 1/

Grass tetany may occur in beef cows grazing tall fescue pastures during the late winter and early spring and is thought to be one of the leading causes of death of adult beef cows in Tennessee. Various investigations have been completed recently or are currently underway to characterize plant and animal responses to forage management that might be related to the incidence of grass tetany.

Chemical composition of tall fescue forage has been studied at Knoxville by D. B. Hannaway and J. H. Reynolds. Fescue forage was sampled monthly for two years to determine the seasonal trends of chemical constituents that may be related to grass tetany. Nitrogen and potassium fertilizer rates were varied to find the influence of fertilization on the chemical constituents. Nitrogen fertilization increased the concentrations of potassium, calcium, and magnesium during some of the months when tetany might occur. Malic acid and total organic acid concentrations were increased by nitrogen fertilization while citric acid was decreased. Potassium fertilization increased potassium but decreased magnesium concentrations in the forage. Malic acid and total organic acid concentrations were decreased and citric acid increased by potassium fertilization. Thus, nitrogen fertilization, at the rates studied--50, 100, and 150 lb. nitrogen per acre--was generally beneficial in changing the chemical composition when compared with the check. On the other hand, potassium fertilization at 150 lb. potassium per acre was detrimental because it decreased magnesium concentration while increasing potassium and citric acid. These conditions have been shown to contribute to grass tetany. Seasonal trends observed showed that calcium and magnesium were lower during the cooler months while potassium and organic acids were increased. These seasonal trends in forage composition would tend to favor grass tetany occurrence in the late winter and early spring.

Animal science research has focused on seasonal trends of blood serum magnesium in beef cows. Monthly samples of blood were obtained from beef cows at a branch station in each major area: East, Middle, and West Tennessee by Hansard et al. Lowest values of blood serum magnesium were found in February, a month when tetany symptoms might be likely to appear. Average monthly serum magnesium values were below the suggested adequate level of 2 mg magnesium per 100 ml of serum.

Another area of attention in animal science research has been the effects of supplemental magnesium on grass tetany incidence in cows grazing stockpiled fescue during the winter. Beef cows fed a MgO-salt mixture or a $MgCl_2$-molasses

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mixture were compared with control cows by McLaren et al. at the Highland Rim Experiment Station, Springfield. The number of clinical cases of grass tetany was reduced and the blood magnesium level was increased by magnesium supplementation. The lowest point in magnesium level during the year occurred at the time of calving. After calving, cows consuming supplemental magnesium had a more rapid recovery of serum magnesium to normal levels than cows not consuming supplemental magnesium.

It appears that low serum magnesium levels in the beef cow after calving may coincide with high potassium, low magnesium, and low calcium concentrations in fescue forage. These conditions would probably be conducive to grass tetany incidence.

Research related to grass tetany currently underway or planned includes the following. F. C. Madsen and S. L. Hansard are monitoring serum magnesium in sheep fed fresh grass supplemented with a readily available caybohydrate source. Persistence of magnesium in fescue forage will be determined by J. H. Reynolds after application of MgO-bentonite slurry to tall fescue leaves. More comprehensive determinations on blood fractions will be made by M. C. Bell and J. B. McLaren. These investigations will also include balance studies in beef cows that are consuming fescue hay and fescue pasture in order to deplete their blood serum magnesium. Seasonal trends of chemical composition of forage samples from tetany-producing pastures will be compared with time of tetany incidence for more complete characterization of causes of grass tetany.

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PROGRAMMING MODELS FOR FORAGE-BEEF SYSTEMS

By W. A. Halbrook 1/

I appreciate the opportunity to appear on your program and visit with you about programming models for forage-beef production systems. This is an area I believe can provide more information for both producers and researchers than the partial analysis of specific production practices. The data requirements, however, are tremendous and require the cooperation of several disciplines. At Arkansas, Dr. Arthur Spooner, Dr. Maurice Ray, and myself have shared the data responsibilities but have been assisted by graduate students and Extension personnel.

Least Cost Forage Programs for Beef Cows

Our first attempt at forage-beef programming was to apply the linear programming minimization model to forage production. Logically, the least cost feed mix and the least cost forage mix for beef cows are the same, but operationally, they are two entirely different problems.

Input-output budgets were developed for a fall-calving cow herd and for each forage species commonly grown in the area. Budgets were developed for four different fertilizer levels for each species and for deferred grazing and hay in addition to seasonal grazing. This provided 12 different production -- harvesting alternatives for each forage species with the options of hay feeding during any month of the year.

Feed requirements were entered in the programming model as minimum amounts of tdn and protein that must be provided each month with monthly limits on the dry matter intake of the animal. Monthly estimates of tdn, protein, and dry matter provided by each production-harvesting alternative were entered as alternative ways of meeting the feed requirements of the herd. Appropriate costs were estimated for each production-harvesting-feeding method.

The objective was to minimize annual costs of feeding the cow herd. All forage feeds were required to be produced on the farm but protein supplement could be purchased if needed. Land costs were varied to provide results that ranged from much land and no fertilizer to high levels of fertilizer and less land.

Results of the least cost forage programs were then considered at different stocking rates and evaluated for a fixed farm size to determine the most profitable stocking rate for different cattle prices.

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Results indicated several data problems but one recognized weakness was the difference between feed required and feed actually consumed under pasture conditions. If only enough feed were provided during the dry period, and if no pasture rationing were practiced, it is possible that the herd might overgraze and damage the stand.

The least cost forage program for beef cows is not a complete systems model but can answer some questions that are not adequately answered with cost-returns budgets.

Forage-Beef Systems Model

About six years ago, a southern regional research project (S-67) was initiated. One objective of this study was to develop a programming model that could be used to evaluate forage-beef production systems in the south. Each state took a slightly different approach to the work, but some general guidelines were established to provide for a certain degree of uniformity.

Some of the general procedures for the study were that (1) each state would develop a set of forage production-utilization budgets that would reflect the costs of producing and utilizing forage feeds, (2) each state would develop a set of beef cattle budgets that would reflect cow-calf, stockers, and feeding activities appropriate to state, (3) minimum amounts of tdn, protein, and maximum amounts of dry matter would be determined for each beef cattle activity from the 1970 edition of "Nutrient Requirements of Beef Cattle," (4) the beef cattle and forage budgets from each state would be reviewed by a committee composed of agronomists, animal scientists, and agricultural economists to provide for as much uniformity as possible, and (5) the forage and beef cattle data would be incorporated into a linear programming model to program the most profitable forage-beef cattle systems for a given set of conditions.

Practically all the basic parts of this objective have been met by the participating states. Forage and beef cattle budgets have been published by most states. Programming work is still in prograss with revisions of price and basic production data. It will probably be another year before programmed results are such that the researchers feel comfortable with the findings.

I would like to share with you some of the problems we encountered at Arkansas with this study. These problems will not be new to many of you since you have been involved with the study in your state.

1. Adequately depicting the Production-Utilization Surface: Production-utilization budgets can be prepared with the best available data and still have programmed results that indicate data weakness. At Arkansas, the early programming results pointed to weaknesses in forage production data at low levels of fertilizer.

2. Data Mass: To adequately depict all the forage-beef alternatives in a linear framework may require up to 500 different forage and beef cattle activities with 20 to 60 bits of information for each. The time and human errors involved in developing this amount of data and converting the data to a programming framework creates several problems.

3. Feed restrictions: Some early programming results indicated that either (1) tdn, protein, and dry matter do not adequately describe feed quality under pasture conditions or (2) our estimates of tdn, protein, and dry matter are not adequate during certain parts of the growing season.

4. Algebra: Maximum dry matter restrictions as used in the model required that any excess capacity be with the animal. This means all dry matter produced must be consumed. On an annual basis, this would be desirable since it would demand complete utilization of the forages. On a monthly basis it may not be economical to stock enough animals to consume all the production during peak production.

5. Proportionality: The proportion of tdn, protein, and dry matter produced are not the same proportions as required by the animals. Since tdn, protein, and dry matter were stockpiled as produced and withdrawn according to animal requirements, this created some programming problems.

6. Economic Obsolescence: The time required to develop programming data can render the prices obsolete by the time results are available. This has been especially true during the last five years.

The above mentioned problems represented challenges to the researchers involved and all have been, or are in the process of being, solved. Rather than dwell on the different methods that have been used to eliminate the programming problems of the S-67 project, I would like to spend the remaining time reviewing some developments that will make forage-beef systems programming more realistic for future research.

Budget generators that have been developed in recent years will make it possible to assign many of the calculations to the computer and thereby reduce human errors, reduce the time involved, and provide for uniformity of calculations. Once a basic set of budgets has been developed it can be updated for changes in prices very quickly and eliminate some of the conomic obsolenscence. It also represents a necessary line in making the programming results applicable to individual farm situations.

Matrix generators are not to the stage of development as the budget generators but, when operational, they will reduce the time required and the errors inherent in transferring budget data to a programming matrix. They represent another tool of making forage-beef systems programming a workable reality.

Computer subroutines have been developed that can quickly calculate the feed reuirements for different beef cattle at different levels of production.

Linear programming will likely be the princiapl model used for general forage-beef systems analysis. However, we are likely to see certain aspects of the "Simulation" model used to supplement the linear model. For certain types of beef cattle analyses, such as cow-calf systems, we may see the linear model supplemented by some of the investment models since certain aspects of beef cow herds fit well into the investment framework;

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